Development of a course on integrating ICT into inquiry-based science education
Title: Development of a course on integrating ICT into inquiry-based science education

Titel: De ontwikkeling van een cursus over integratie van ICT in onderzoekend leren in de natuurwetenschappen

Dissertation Vrije Universiteit Amsterdam. Met een samenvatting in het Nederlands.

ISBN: 978-94-92496-00-3

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Printed by MarcelisDécavé, Alkmaar, the Netherlands

Cover illustration: Trinh-Ba Tran

This dissertation was made possible by a grant of the Ministry of Education and Training of Vietnam. The research was carried out in the context of the Dutch Interuniversity Centre for Educational Research (ICO) and was facilitated by the Vrije Universiteit Amsterdam and the Dutch Centre for Microcomputer Applications (CMA).
Development of a course on integrating ICT into inquiry-based science education

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. V. Subramaniam,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de Faculteit der Gedrags- en Bewegingswetenschappen
op dinsdag 28 juni 2016 om 9.45 uur
in het auditorium van de universiteit,
De Boelelaan 1105

door
Trần Bá Trịnh

geboren te Hanam province, Vietnam
promotoren: prof.dr. J.J. Beishuizen
prof.dr. A.L. Ellermeijer
copromotor: dr. E. van den Berg
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Chapter 1 Introduction

1.1 Background

1.1.1 ICT and science teachers
Since the beginning of the 1980s, the international science-education community has widely recognised the possibilities of Information and Communication Technology (ICT) as innovative tools in school science activities. First, tools for gathering data with sensors and for dynamical modelling became available. Later on, the multimedia power of computers enabled video measurement and simulations. Development of the ICT tools for data logging with sensors, video measurement, and dynamical modelling from the start was guided by design principles originating from science education research and aimed at classroom use. Meanwhile, many other ICT applications in science education were not specially designed for education. They were designed primarily a) for scientists and engineers such as the Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW), b) for professional use such as Microsoft office software, and c) for personal use such as tablets, smartphones.

Avoiding the distraction by complex technical details, the ICT tools for data logging, video measurement, and dynamical modelling have been able to keep the technical skills required for teachers and pupils limited. However, these ICT tools can only be incorporated effectively into science activities of pupils if teachers are motivated and able to make use of the tools. Tamim, Bernard, Borokhovski, Abrami, and Schmid (2011), in a synthesis of more than 25 meta-analytic studies, claimed that the role of the teacher in technology-enhanced learning of pupils is inevitable and even more important than the incorporation of the technology itself. According to Newton and Rogers (2001), this role requires from the teacher skills to operate the actual software and hardware as well as procedural and pedagogical skills to teach with these ICT tools in the classroom.

1.1.2 Inquiry, ICT, and science education
The recognition of inquiry as an important learning goals for science education and as a pedagogy for learning science goes at least back to Dewey (1910, 1916) and has been emphasised again and again in major curriculum policy documents such as Rocard et al. (2007), Duschl et al. (2007), and NRC (2012). Throughout this dissertation, the term “inquiry” will refer to a) the way scientists generate and validate knowledge in science research and b) learning goals and teaching strategies in school science education. The current framework for primary and secondary science education in the United States (NRC, 2012) argues that if the teaching of science only focuses on the acquisition of subject matter, then pupils will not understand features of scientific inquiry, and they might wrongly view science just as a collection of isolated facts. Inquiry as learning goal of science education consists of both understanding about inquiry (i.e. how knowledge is generated and validated) and the ability to conduct inquiry (i.e. inquiry skills) (Miner, Levy, & Century, 2010; NRC, 1996). Inquiry as a teaching strategy provides pupils with opportunities to exercise inquiry practices (NGSS Lead States, 2013) through a) hands-on experience (physically active) and b) minds-on discussion, meaning making (mentally engaged).
Chapter 1

It has been demonstrated that the proper use of the ICT tools for data logging, video measurement, and modelling will a) enable pupils to achieve better understanding of science concepts and b) stimulate them to conduct science activities with similar tools like those of scientists (Donnelly, Linn, & Ludvigsen, 2014; Gerard, Varma, Corliss, & Linn, 2011; Heck & Ellermeijer, 2014). However, inquiry goals cannot just be achieved by doing only. Just like the learning of any complex skills, the acquisition of inquiry skills needs to be carefully designed and scaffolded (van Merriënboer, Clark, & de Croock, 2002). According to Kirschner, Sweller, and Clark (2006), the way for pupils to understand inquiry is to get them involved in the knowledge creation activity and to make this inquiry process explicit to them. ICT tools can help to realise these inquiry goals by providing more opportunities for inquiry within experimentation/modelling activities.

Reports of international organisations (i.e. OECD, PISA), international projects (i.e. ESTABLISH, SAILS), and curriculum documents (e.g. NGSS: Next Generation Science Standards) show that ICT-enhanced and inquiry-based activities are integral components of the intended science curricula in many countries. ICT and inquiry are incorporated at both the primary and secondary levels as learning goals and/or teaching strategies. The use of ICT tools in school science and/or Inquiry-Based Science Education (IBSE) has been a central topic in many international projects. For example, the “ICT for Innovative Science Teachers” (ICT for IST) project; the “Kicking Life into Classroom” (KLiC) project; the Fibonacci project; the “European Science and Technology in Action: Building Links with Industry, Schools and Home” (ESTABLISH) project; and the “Strategies for Assessment of Inquiry Learning in Science” (SAILS) project1. This shows that the use of ICT, as well as IBSE, is not limited to a few extravagant curricula. Incorporation of ICT and inquiry in the science curriculum is promoted at the international level and advanced further through these ICT/IBSE projects. Within these projects, extensive support materials were developed for innovative teaching and learning of science with ICT and/or IBSE. These materials were then used in the pre- and in-service teacher-education initiatives to promote good practices of ICT and/or IBSE in the classroom.

1.2 Problem definition and research scope

1.2.1 Implementation of ICT and IBSE in teaching practice

ICT and IBSE with innovative features have been available for more than thirty years and have been included in the intended science curricula. The science education community mostly agrees about the relevance of using ICT, IBSE, and their integration: ICT in IBSE for pupils exercising inquiry practices, acquiring inquiry skills, and understanding scientific inquiry. However, ICT, IBSE, and ICT in IBSE are still not implemented sufficiently and

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1 ESTABLISH project: http://www-establish-fp7.eu/
Fibonacci project: http://fibonacci.uni-bayreuth.de/home.html
ICT for IST project: http://ictforist.oeiizk.waw.pl/
KLiC project: http://www.klic-project.eu/
SAILS project: http://www.sails-project.eu/portal
properly in the classroom in most countries. Abrahams and Millar (2008) summarised results of observations in 25 typical laboratory lessons in the United Kingdom as follows:

Practical work was generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect. (p.1945)

Teachers sometimes try to apply ICT tools (e.g. data logging with sensors) in the classroom, but mostly in traditional ways in which they provide a prescriptive list of tasks for pupils to follow ritualistically. Meanwhile, pupils know in advance from the textbook what the results of the practical work should be (Hofstein & Lunetta, 2004). Prescriptive instruction enables pupils to operate the ICT tool on their own (manipulation of equipment), but such instruction limits inquiry opportunities for pupils (manipulation of ideas).

On the other hand, assignments aiming at inquiry learning have a high cognitive load for pupils (Kirschner et al., 2006). Furthermore, a number of studies have reported that teachers often find it difficult to elicit, guide, and manage inquiry learning of pupils (e.g. Davis, Petish, & Smithey, 2006; Hofstein & Lunetta, 2004). These findings lead us to the conclusion that ICT-enhanced inquiry-based strategies have proved their potential, but not their general efficacy in the hands of average teachers. Science teachers need effective training and practical guidelines to handle the complexity of the ICT-enhanced, inquiry-based activity without reducing it to simple “cookbook recipes”.

International ICT projects (e.g. KLiC and ICT for IST) highlighted possibilities and good practices of ICT tools for IBSE but were not of the scale needed to bring about the substantial impact on classroom implementation. At the national level, in many countries (e.g. Greece, Russia, and Ireland), governmental education-reform projects have invested in ICT apparatus and software, delivered it to schools nationwide, and provided teachers with short training. Meanwhile, knowledge-oriented curriculum objectives and paper-and-pencil assessments were not reformed. Eventually, sufficient and proper implementation of the ICT tools was not realised. In this situation, projects with a huge funding failed to make the intended change in the classroom due to lack of consistent and concerted efforts to design, align, and implement curriculum innovation regarding ICT integration.

1.2.2 Scope of the research

As discussed in preceding sections, ICT and IBSE are relevant in science education and have been available for a long time, but are still very much underused. According to Bennett (2005), Novak and Krajcik (2004), Brummelhuis, Wijngaards, Swager, and van Goozen (2010), factors involved are amongst others:

- limited curriculum time and limited teacher preparation time;
- lack of equipment, resources, and technical support;
- the mismatch between assessment and curriculum objectives (i.e. inquiry);
- pupil problems (e.g. high cognitive load of inquiry learning);
- teacher problems (e.g. prescriptive instruction with ICT) and lack of continuous teacher education.

All of these factors need to be changed consistently and in concert to realise incorporation of ICT and IBSE in the classroom. Fullan (2007) has drawn attention to the fact that what
teachers do and think is crucial for any educational reform. Therefore, we focus on teacher preparation and training on ICT and IBSE, which are key forces for driving change regarding ICT and IBSE incorporation in classroom practice. The challenge is how to bring a large number of teachers nationwide to a certain level that ICT and IBSE are implemented sufficiently and sustainably in the classroom. This level requires from teachers the ability to a) learn skills to operate ICT tools mostly on their own and b) to design, try out, and evaluate ICT-enhanced, inquiry-based activities independently.

We decided to take up the challenge and develop a teacher-education course on the effective use of ICT to enhance IBSE in the science classroom (i.e. ICT in IBSE). Following a design research approach, we cooperated with teacher educators to develop a short course, which is effective and which can be flexibly adapted to and incorporated in existing pre- and in-service teacher-education programmes. We considered "short" as a boundary condition of the course. “Short” is in the sense of the relatively limited contact time and self-study time (e.g. 12 contact hours plus about 16 assignment hours). This consideration resulted from the fact that existing postgraduate pre-service programmes, in the Netherlands for instance, are tight and do not allow much room for specialised contents like ICT in IBSE. Additionally, time constraints are also the case for in-service courses as school teachers cannot take many days off for professional development due to the demanding job and full curriculum. In short, the present research focussed on developing a short, university-based course for pre and in-service science teachers on ICT in IBSE. It did not investigate how to incorporate ICT and IBSE into the school curriculum.

Concerning objectives of this short ICT in IBSE course, we did not focus on either application of ICT in teaching specific concepts or implementation of IBSE without ICT. We focussed on the integration of ICT into IBSE; the integration must stimulate and support pupils to exercise inquiry skills through experimentation and/or modelling activities. In this dissertation, we use the abbreviation “ICT in IBSE” to refer to this focus. We limited the ICT to tools for data logging with sensors, video measurement, and dynamical modelling in school science. We did not include other uses of ICT such as the use of simulation applets to support concept development.

About evaluation of the short ICT in IBSE course, we measured teachers’ knowledge, skills, and motivation gained through the course and collected evidence whether they used such knowledge and skills after the course in their lessons. During the course, the participating teachers were required and supported to design and then try out an ICT in IBSE lesson in the classroom. According to Millar (2010), it is unreasonable to expect durable long-term learning of a scientific idea to result from a single, relatively brief lesson. Learning, when it occurs, results from a sequence of lessons that are carefully planned. Therefore, we did not focus on the impact of the ICT in IBSE lesson on pupils’ learning. For classroom observations, we focused on the teaching of teachers.

Educational theories and products, such as our course, do not always travel well as educational and cultural contexts in different schools and countries can be very different. Moreover, in different phases of professional development, teachers have different motivations and difficulties in learning to use and apply new teaching methods and tools such as ICT in IBSE. That is why the present research included three countries (i.e. the
Netherlands, Slovakia, and Vietnam) and both pre- and in-service teacher education. That way we could test the transferability of our course design and the generalizability of the pedagogical principles at the basis of this design.

1.3 Research questions and methodology

1.3.1 Research aims and questions

The general aim of this research was to design an effective, short course for teachers to learn to integrate ICT into IBSE and stimulate inquiry by pupils. The design of the short ICT in IBSE course had to be flexible enough to be applied in different educational and cultural contexts of pre- and in-service teacher education in different countries. The present research was guided by the following interconnected research questions:

1. What are characteristics of an effective, short course for Dutch student teachers to learn to apply ICT tools for data logging, video measurement, and modelling in inquiry-based science education? (the ICT in IBSE course)

2. To what extent is the ICT in IBSE course applicable in different educational and cultural contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam)?

Figure 1.1. The design research process including an explorative phase and a cyclic-research phase in relation with chapters of this dissertation.

Notes about abbreviations:
- NL Cycles 1, 2, and 3 were three iterative cycles of the Dutch version of the ICT in IBSE course. NL Cycle 4 was a cycle, which was not in the iteration, but for a robustness test of the Dutch course (Chapter 4).
- SK Cycles 1 and 2 were two iterative cycles of the Slovak version of the ICT in IBSE course (Chapter 5).
- VN Cycle 1 was only one cycle of the Vietnamese ICT in IBSE course (Chapter 6).

1.3.2 Research methodology

To address these research questions, we followed a design research approach (Figure 1.1). We first addressed the question: what does the literature suggest about pedagogical principles underlying an effective, short course on ICT in IBSE for teachers? (Chapter 2) Next, considering course objectives, defined pedagogical principles, and selected support
Chapter 1

materials, we elaborated an initial scenario for the ICT in IBSE course in the Dutch context of pre-service teacher education. The course scenario described what the participant was expected and supported to do to achieve the course objectives. It included a programme of particular activities in live sessions (incl. content, format, and timing) and explicit requirements for individual assignments (Chapter 3).

The initial scenario of the Dutch ICT in IBSE course was then implemented, and its implementation was evaluated. In this dissertation, the term “cycle” is used to refer to a research phase in which we implemented and evaluated the course. Of four cycles in the Dutch context, the first two cycles focussed on evaluation for optimisation of the course. Problems found in the evaluation of the course in the first cycle suggested revisions of the course scenario. These revisions were aligned with the pedagogical principles and aimed at more faithful and effective implementation of the course. The revised scenario was evaluated in the second cycle and then revised for the third cycle (Figure 1.1). After two iterations of refinement, summative outcomes of the Dutch version of the ICT in IBSE course were evaluated in the third cycle, and only minor suggestions were made for further optimisation. Outcomes of the Dutch course in routine mode without the extra support of the researcher were evaluated in the fourth cycle to test for robustness (Chapter 4).

Meanwhile, the initial scenario of the Slovak ICT in IBSE course was elaborated and adapted from the general design of the course (i.e. objectives, pedagogical principles, support materials), considering the Slovak context (e.g. participants, timeframe, and school conditions) (Table 1.1). The initial scenario of the Slovak course was evaluated in a first cycle and optimised once. Summative outcomes of the Slovak version of the ICT in IBSE course were evaluated in a second cycle (Chapter 5). Likewise, the scenario of the Vietnamese ICT in IBSE course was adapted from the general design of the course, considering the Vietnamese context. The Vietnamese course was implemented and evaluated in only one cycle (Chapter 6).

Table 1.1. Overview of three case studies about three versions of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam.

<table>
<thead>
<tr>
<th>Context of the course</th>
<th>Total study time/ contact hours</th>
<th>Number of cycles</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>A pre-service course within the Dutch teacher-education programme</td>
<td>28 hours/12 hours</td>
<td>4</td>
<td>40 physics/chemistry student teachers spread over four sequential cycles; they were either in a teaching internship or in the first years of a teaching job.</td>
</tr>
<tr>
<td>An in-service course within the Slovak accredited professional-development system</td>
<td>40 hours/25 hours</td>
<td>2</td>
<td>66 physics/biology/chemistry teachers, spread over two sequential cycles; their teaching experience varied from 1 to 33 years.</td>
</tr>
<tr>
<td>A master course within the Vietnamese Master programme on physics education</td>
<td>60 hours/30 hours</td>
<td>1</td>
<td>22 master students in physics education, taking part in one cycle; some had taught for 2 to 9 years; others came straight from a Bachelor teacher-education programme.</td>
</tr>
</tbody>
</table>
1.4 Context and relevance

1.4.1 Context of the research

This section is to present the context in which the PhD project was conducted and clarify connections between this context and choices that we made for the research. We organised and carried out three case studies in three countries: the Netherlands, Slovakia, and Vietnam. The Vietnamese PhD candidate and his three Dutch supervisors were all involved in all aspects of the Dutch course and the study in this context (Chapter 4). The Dutch course was a joint, short pre-service course within the postgraduate teacher-education programmes of VU Amsterdam (VU), Utrecht University (UU), Delft University of Technology (TU-Delft), and the University of Amsterdam (UvA) in cooperation with the Centre for Microcomputer Applications (CMA).

For the Slovak case study (Chapter 5), we collaborated with two Slovak teacher educators (both PhD holders), who arranged and taught the Slovak ICT in IBSE course. It was in the context of a short in-service course at Pavol Jozef Safarik University in Kosice. The Slovak course was adapted to fit the national accreditation system for teacher professional development. There was frequent communication with the two Slovak teacher educators via email about the course objectives, the course scenario, support materials, data collection, and data analysis. The PhD candidate came to Slovakia and observed the final sessions of the Slovak course in the second cycle.

For the Vietnamese case study (Chapter 6), we arranged and implemented the Vietnamese ICT in IBSE course in cooperation with a Vietnamese teacher educator (PhD holder). It was a short, specialised course within the Master programme on physics education at Hanoi National University of Education (HNUE). One of the supervisors came for observation of the final part of the course. He observed all of the master students’ live presentations and was able to attend 9 (out of 22) classroom try-outs of the ICT in IBSE lessons. For all Dutch, Vietnamese, and Slovak contexts, the ICT in IBSE course was a new, specific course, which the local teacher educators were interested in and eager to try out in their teacher-education programmes.

In text formulations of this dissertation, the subject “we”, object “us”, and pronoun “our” refer to the research team, including the PhD candidate and the PhD supervisors. When describing roles of individuals in implementing and evaluating the course, we use the term “researcher” referring to the PhD candidate. We use the term “pupil” referring to “secondary school student” to avoid confusion with participants of the ICT in IBSE course. These participants were either student teachers in the Netherlands, physics-education master students in Vietnam, or teachers in Slovakia. We call them “course participants” when discussing the course, and we call them “teachers” when writing about their ICT in IBSE try-outs in the schools.

1.4.2 Relevance of the research

The present research is to investigate 1) whether or not it is possible to develop an effective, short ICT in IBSE course and 2) whether or not this course is flexible enough to be applied in different countries. If so, which adjustments have to be made in the
Chapter 1

pedagogical principles guiding the design of the course? The first aim refers not only to a concrete design of the ICT in IBSE course for teachers but also to pedagogical principles at a higher level of abstraction. The second aim refers to the extent to which these pedagogical principles are generalizable over cultural contexts. With these aims, the relevance of the present research is quite balanced between development and research, between practical and theoretical contributions.

Concerning practical contributions, this design research aimed at developing a short ICT in IBSE course as an educational product, which fulfils the following criteria:

- Design specifications of pedagogical principles have to be implemented faithfully;
- The course has to achieve its objectives;
- The course design has to be adaptable and applicable in different educational and cultural contexts in the Netherlands, Slovakia, and Vietnam.

The adapted course scenario in each country along with support materials will constitute a practical reference for teacher educators, who are going to prepare similar ICT/IBSE courses for pre- or in-service teacher education.

About theoretical contributions, we did not investigate new pedagogical principles but tested our selection and operationalization of principles from the literature on their relevance for facilitating effective teacher learning in the context of a short ICT in IBSE course. We did not try out different selections of pedagogical principles and compare the resulting effects. Rather, we tested the transferability of the course design based on the same principles in different cultural and pedagogical contexts. The test was to prove that the pedagogical principles not only bring the success of the course circumstantially, but they are also effective and applicable in different circumstances of teacher education. **If the pedagogical principles hold up in different contexts, that adds to their validity (external validity).** So it is not only interesting to test a course design in different countries, it is also a test of generalizability of the pedagogical principles. Eventually, we planned to recommend pedagogical principles and course design, validated through the case studies in the three countries, to those who are going to conduct a design research about teacher education in a similar domain. The recommendations also concern the minimum conditions needed for successfully operationalising and implementing these principles.

The research defined what and how to teach during the ICT in IBSE course (Chapters 2 and 3). Data, collected then (Chapters 4, 5, and 6), shed light on how the course objectives were achieved by the participants. The research was intended to contribute to **understandings of how teachers learn to use and apply ICT in IBSE.** The gained knowledge about when and why teachers are stuck in this learning process will enable teacher educators to support teachers timely to get over the difficulties. So that the teachers can learn further in this specific ICT in IBSE domain during and after the course. In the final discussion and conclusions (Chapter 7), we will return to the potential theoretical and practical contributions and check which were realised or which were not. If not, what were the reasons?
1.5 Outline of the dissertation

The dissertation chapters are presented in the order in which different phases of the present research were carried out (Figure 1.1). Chapter 1 defines the research problems and provides an overview of the research. In Chapter 2, we explore relevant literature, take pedagogical considerations for the design research, and define the pedagogical principles underlying the short ICT in IBSE course. The chapter ends with a discussion of design research methodology behind the development and evaluation of the course in different countries. Chapter 3 describes the initial scenario and the framework to optimise and evaluate the ICT in IBSE course.

The optimisation and evaluation of the Dutch course are presented in Chapter 4. Specific adaptations made for the different countries and related research results are presented and discussed in Chapter 5 (Slovakia) and Chapter 6 (Vietnam). Chapter 4 ends with the conclusion for the first research question: what are characteristics of an effective, short course for Dutch student teachers to learn to apply ICT tools for data logging, video measurement, and modelling in inquiry-based science education? In Chapter 7, we return to connect the pedagogical principles to the literature and reflect on the second research question: to what extent is the ICT in IBSE course applicable in different educational and cultural contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam)? This chapter ends with implications and recommendations for future research and development concerning teacher education, IBSE, and ICT integration in science education.
Chapter 2 Background and considerations

Chapter 2 explains the theoretical background of this research. In particular, Section 2.1 considers the relevance of ICT in IBSE and its challenges for teachers and pupils. Based on these considerations, we propose a realistic, but worthwhile approach to such challenges within the short course as well as a long-term vision that stimulates participants to continue applying ICT in IBSE after the course. Section 2.2 analyses the framework of teacher knowledge with regard to ICT in IBSE teaching and the framework for designing, executing, and evaluating a particular ICT in IBSE lesson. How these frameworks were used for designing, implementing, and evaluating the course is also discussed in this section. Section 2.3 focuses on teachers as learners during their career trajectory and searches for an effective model of teacher education, especially for ICT integration. These first three sections end with explicit definitions of four objectives of the ICT in IBSE course. In Section 2.4, we explain our choice of a design research approach and define four pedagogical principles underlying the ICT in IBSE course with respect to the pre-defined objectives and the general time-constraint condition. The chapter ends with summative considerations for the next steps of this design research, which will be presented in the next chapters.

2.1 Integration of ICT into IBSE: relevant but challenging

2.1.1 Inquiry-based science education

In this section, we explain how we define inquiry as a means to create knowledge and clarify its position in science curricula as a crucial learning goal and a teaching strategy. The section ends with pedagogical considerations for the ICT in IBSE lesson that participants designed and tried out within the ICT in IBSE course.

a) Inquiry and how pupils learn

Science educators have been aware of the potential benefits of an inquiry-based approach in science teaching and learning at both primary and secondary levels, and the term “Inquiry-Based Science Education” - IBSE has been popular for a long time. In an article published in 1910, Dewey remarked that science is not only a body of knowledge to be acquired, but it also includes inquiry methodologies to generate and validate knowledge. In this present research, we consider inquiry as a process of generating and validating knowledge through moving back and forth between the theoretical world (ideas, concepts, relationships, theories, and models) and the physical world (objects, phenomena, observations, measurements, and experiments) (Figure 2.1). According to Van den Berg (2013), ideally, IBSE will engage pupils in thinking back and forth between these two worlds like scientists; and “the phenomena and experiments serve as a source for validating ideas and theories and as a playground for generating new ideas and theories in a complex mix of inductive and deductive mind play” (p.75). Illustrative photographs in Figure 2.1 are about an inquiry activity of three Vietnamese pupils. In the theoretical world, these pupils proposed a conceptual design of an experiment (by sketching) to verify the value of the acceleration due to gravity (g). Next, they moved into the physical world to set up and carry out the
experiment, following their own design. After collecting sufficient data, they moved back to
the theoretical world and used kinematics to analyse these data and validate the value of \( g \),
which was given in the textbook.

### Generating and validating knowledge

<table>
<thead>
<tr>
<th>Theoretical world</th>
<th>Physical world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concepts, Relations, Theories, Models</td>
<td>Phenomena, Observations, Measurements, Experiments</td>
</tr>
</tbody>
</table>

*Figure 2.1. Moving back and forth between the theoretical world and the physical world is the inquiry way to generate and validate scientific knowledge (adapted from Van den Berg, 2013, p.75).*

**Inquiry as process of generating and validating knowledge** fits into a view on learning as knowledge creation, discussed by Paavola, Lipponen, and Hakkarainen (2004). Inquiry, under the knowledge-creation perspective, is the process whereby new knowledge and understandings are (re)constructed. From the knowledge-creation perspective, knowledge is not always objectively true. Knowledge is not always given by teachers and scientists or in other knowledge containers (e.g. journal articles, textbooks). Knowledge and its representations (e.g. ideas, concepts, relationships, theories, and models) can also be created, elaborated, and restructured by learners and researchers. This is in line with Duschl, Schweingruber, and Shouse (2007) that the brain is filled with preconceptions from early life experiences; some of these preconceptions match with science, others do not. Therefore, much learning involves reconstruction of prior ideas, which are already in the learner’s brain. In addition to the knowledge-creation model, Paavola et al. (2004) discussed two other metaphors of learning: acquisition and participation. The knowledge-acquisition metaphor focuses on learning within individuals’ minds, whereas the participation metaphor emphasises learning as a process of participation in various practices and activities. The knowledge creation perspective encompasses both acquisition and participation.

In the book: “The scientist in the crib”, Gopnik, Meltzoff, and Kuhl (1999) implied that from young ages, children can create new knowledge by inquiry, and scientists make the most of this capacity, which lets “children learn so much so quickly” (p.9). Consequently, we indeed concur with Duschl et al. (2007, p.83) that pupils are able to “engage in and profit
from instruction that incorporates relatively complex scientific practices from the very beginning of their schooling”.

b) Authentic inquiry of science

The science-education community has suggested making *authentic inquiry* of science more accessible to pupils (e.g. Gaskell, 1992; Edelson, 1998; Braund & Reiss, 2006). Authenticity of inquiry in the school can be interpreted as resemblance of pupil activities to experimentation/modelling activities of practicing scientists in constructing new knowledge, considering the three following aspects (Heck, 2009):

1. *A real-life context for learning* that provides pupils with opportunities to investigate realistic science problems in history or present-day research and so pupils will appreciate the relevance of scientific knowledge in everyday life.
2. *Tools and techniques* that enable pupils to carry out experiments or modelling and to analyse and process high-quality data in much the same way scientists do.
3. *Scientific attitudes of learning* that stimulate pupils’ pursuit of unanswered questions, commitment to challenging tasks, and social interactions (e.g. cooperation, argumentation).

Authentic inquiry is close to real science, so makes school science more attractive and relevant. This might be part of a solution for the fact that there has been a decline in interest for science at high school (OECD, 2006). Moreover, considering the “learning as participation” metaphor (Paavola et al., 2004), pupils can appreciate inquiry as a scientific method of generating and validating knowledge through being engaged in practices similar to those of scientists. Additionally, authentic inquiry can be realised in the school. For example, the Dutch curricula require pupils to gain exposure to research projects in science and other subjects where they have to make their own choices with respect to topic, questions, and experiments/models; collect and analyse data; and compare outcomes with literature. A final investigation project is intended for 80 hours outside of regular lessons and spread over a whole school year (about 2 hours a week). Research showed that some Dutch pupils in their research projects actually:

- apply ICT tools autonomously in doing research like that of scientists;
- obtain results comparable with results published in scientific/professional journals


c) School science and inquiry practices

IBSE is an integral component of the intended science curricula in many countries (Jeskova et al., 2015a). In such school science curricula, “inquiry” refers to *learning goals* (i.e. understanding of the methods of scientific inquiry and the ability to carry out scientific inquiry). “Inquiry” also refers to *teaching strategies* that stimulate and support *pupils to exercise inquiry practices*, including hands-on activities, minds-on discussions, and meaning making (Hodson, 2009; Minner et al., 2009; NRC, 2012). What do we see in a classroom where inquiry-based teaching shows up, and inquiry goals seem to be realised? Ash and Kluger-Bell (2000, p.80-81) described this in Table 2.1.
Table 2.1. Observable components of inquiry practices of pupils in the science class (Kluger-Bell, 2000, p.80-81).

| Pupils raise questions | • They ask questions - verbally or through actions.  
  | • They use questions that lead them to investigations (e.g. experimentation, modelling) and that generate or redefine further questions and ideas.  
  | • They value and enjoy asking questions as an important part of science. |

| Pupils use observations | • They observe carefully, as opposed to just looking.  
  | • They see details, seek patterns, detect sequences and events; they notice changes, similarities, and differences.  
  | • They make connections to previously held ideas. |

| Pupils plan and carry out investigations | • They design a fair test as a way to try out their ideas, not expecting to be told what to do.  
  | • They plan ways to verify, extend, or discard ideas.  
  | • They carry out investigations by handling materials with care, observing, measuring, and recording data. |

| Pupils propose explanations and solutions and build a store of concepts | • They offer explanations both from a "store" of previous experience and from knowledge gained as a result of ongoing investigation.  
  | • They use investigations to satisfy their own questions.  
  | • They sort out information and decide what is important (what does and does not work).  
  | • They are willing to revise explanations and consider new ideas as they gain knowledge (build understanding). |

| Pupils critique their science practices | • They create and use quality indicators to assess their own work.  
  | • They report and celebrate their strengths and identify what they'd like to improve upon.  
  | • They reflect with adults and their peers. |

Until recently, science educators used the term: “inquiry skill” for skills that can be observed in a classroom as mentioned in Table 2.1. These were seen as relatively separate from knowledge, whereas “inquiry” is always coupled with generation and/or validation of knowledge; an inquiry-based activity always includes conceptual elements. To reflect on the complex nature of inquiry skills and the entanglement with domain knowledge, the Next Generation Science Standards (NGSS) in the United States uses the term “practice” (NGSS Lead States, 2013). Based on definitions of scientific inquiry, the current framework for primary and secondary science education in the United States (NRC, 2012, p. 49) distinguishes the following crucial practices of inquiry-based science activities in the classroom:

- Asking questions
- Developing and using models
- Planning and carrying out investigations (incl. experiments)
- Analysing and interpreting experimentation/modelling data
- Using mathematics and computational thinking
- Constructing explanations
- Engaging in argument from evidence (i.e. experimentation/modelling outcomes)
- Obtaining, evaluating, and communicating information
Most of these inquiry practices (e.g. interpreting data, constructing explanations, and engaging in argument from evidence) require pupils to think back and forth between the physical world and the theoretical world. The NGSS described the essentials of these practices as follows:

Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. (NGSS Lead States, 2013, p.48)

d) Learning to do inquiry

Although engaging in inquiry practices is crucial to understand scientific inquiry and to learn inquiry skills, it is not enough. According to Chinn and Malhotra (2002), many inquiry activities *replicated in the classroom* fail to help pupils to appreciate inquiry as a scientific method. Moreover, the first review of research on effectiveness of teaching in the laboratory (Bates, 1978) concluded that there was no evidence for better conceptual or inquiry skill achievement for pupils with as compared to without laboratory experience. Recent reviews (e.g. Lunetta, Hofstein, & Clough, 2007; Millar, 2010) still showed that the objectives for laboratory teaching (incl. inquiry skills) – just as with other teaching methods – are often not achieved.

For pupils really acquiring inquiry skills and understanding about scientific inquiry, as Akerson, Abd-El-Khalick, and Lederman (2000) argued, there must be an explicit emphasis on the method of scientific inquiry and reasoning as pupils are exercising such inquiry skills in the classroom. Especially for the first time, inquiry skills have to be explicitly taught and scaffolded (Kirschner et al., 2006; Abrahams & Millar, 2008).

e) Pedagogical considerations for our ICT in IBSE course

What we have learned from the literature study are: pupils’ acquisition of inquiry skills is an important goal of science education. Ideally, participation in inquiry practices similar to those of practicing scientists will enable pupils to understand scientific inquiry. Inquiry fits the way pupils learn from young ages, but to really master inquiry as a scientific method, pupils need explicit teaching of inquiry while exercising inquiry practices.

Consequently, we focused on pupils acquiring inquiry skills as one of the crucial goals of the ICT in IBSE lesson. To realise this goal, we chose explicit inquiry-based teaching as the main approach. With “explicit” we mean that a) pupils consciously exercise intentional inquiry skills and b) the teacher guides and scaffolds this process. Via the course description and in first sessions, we had to make the participants aware of these goals and methods to teach inquiry skills.

2.1.2 Integration of ICT in IBSE: relevance in stimulating inquiry practices

Since the 1980s, advances in technology and science education research have stimulated intensive development of ICT tools for 1) data logging with sensors, 2) video measurement, and 3) dynamical modelling. Data processing and analysis are generic and integrated components of all three tools for data logging, video measurement, and modelling. These tools resemble those of scientists and engineers, but are designed for educational purposes and primarily aimed at classroom use. In this section, we describe characteristics and
educational benefits of this ICT as constructional tools for science education. Furthermore, we explain how all three ICT tools can enhance opportunities and time for pupils’ construction of knowledge in the science class (Figure 2.2) through moving back and forth between the theoretical and physical worlds. Among the three tools, it is possible to distinguish:

- data logging with sensors and video measurement as tools for pupils’ experimental inquiry (collecting data in the physical world),
- dynamical modelling as a tool for pupils’ theoretical inquiry (generating data in the theoretical world).

This section ends with the rationale for our selection of these ICT tools among other available ICT applications and pedagogical considerations for our ICT in IBSE course.

Figure 2.2. Photographs of pupils engaged in experimentation/modelling activities, which were enhanced by the ICT tools for data logging with sensors, video measurement, and dynamical modelling. These photographs were taken from the classroom try-outs of participants within the ICT in IBSE course.

a) A holistic picture of ICT applications in science education

Papert (1999) divided ICT applications for teachers and pupils into two main categories: “ICT as an informational medium” and “ICT as a constructional medium” (Table 2.2). The author aligned this classification with his viewpoint: “education itself has two wings which also could be called “informational” and “constructional” (p. XI-XII). One aspect of learning is about getting information by listening to lectures, reading textbooks, or googling the Internet, and the other aspect is about doing, making, and constructing “things” (e.g. concepts, theory, models, and experiments). According to this classification, ICT applications in the informational wing focus on providing accumulated knowledge. Those in the constructional wing serve as tools for constructing new knowledge and understanding, so are relevant for stimulating inquiry practices of pupils (Figure 2.2).
Table 2.2. Classification of ICT applications in science education.

<table>
<thead>
<tr>
<th>ICT as an informational medium</th>
<th>ICT as an constructional medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Information system (e.g. web 2.0, Wikipedia, YouTube, Google, cloud storage, DVD)</td>
<td>• Data logging with sensors</td>
</tr>
<tr>
<td>• Online communication (e.g. social media, video conferencing, SMS)</td>
<td>• Video measurement</td>
</tr>
<tr>
<td>• Multimedia presentation (e.g. PPT slides, Prezi, digital textbooks, mind-mapping tools)</td>
<td>• Dynamical modelling</td>
</tr>
<tr>
<td>• Presentation devices (e.g. beamer, interactive whiteboards, TV)</td>
<td>• Data processing and analysis (i.e. separate spreadsheet programme or integrated part of other tools)</td>
</tr>
<tr>
<td>• Virtual learning platform (e.g. tutorial courseware, Moodle, eLearning software)</td>
<td>• Simulation applications and applets (e.g. PhET, Crocodile Physics)</td>
</tr>
</tbody>
</table>

b) The ICT tool for data logging with sensors

**Characteristics.** The ICT tool for data logging with sensors enables pupils’ experimentation activities in which the sensor, connected to an interface, measures a quantity (e.g. temperature, voltage, and pH) in the physical world and transforms this quantity into a voltage or other signal, which is then read by the interface. The interface converts the signal into digital data that are transferred to, then interpreted and processed by the connected computer or other devices with dedicated software (Figure 2.3).

![Diagram of the tool for data logging with sensors](image)

Figure 2.3. Diagram of the tool for data logging with sensors (incl. sensor, interface, and computer with dedicated software).

A computer equipped with an interface and ample sensors becomes a *universal measuring instrument*, which has a wide range of sampling frequencies from *very low to very high* (e.g. 10000 samples per second). This computer-based instrument certainly can take the place of instruments such as thermometers, voltmeters, pH meters, used in conventional practical work. It enables *automatic, accurate, conditional measurements* and includes *ample ways* of storing, displaying, and analysing data. During the measurement, real-time data can be represented in graphs, tables or displayed as digital values. Among different software packages, there are three common measurement methods:

- **Time-based measurement** in which data are automatically gathered at regular time intervals according to the sampling frequency. With this setting, it is *possible to specify a signal condition* from which the computer automatically starts a measurement (i.e. triggering). For example, Figure 2.3 shows time-based measurements of water temperature and the obtained graph displays how the temperature changes over time.

- **Event-based measurement** in which measurements are taken each time a pulse (i.e. an event) is received on an interface input. For example, in an experiment
Chapter 2

with stroboscopic light, each light flash generates a pulse via a light sensor, and then a measurement is taken.

- Manually-triggered measurement in which a single measurement is taken every time the user presses a button. This setting also allows to type in data (e.g. observational data, standards, given values) via the keyboard. For example, in the Boyle’s law experiment, pressure of air, which is trapped inside a cylinder fitted with a piston, is measured by a pressure sensor each time a value of gas volume read by naked eyes is manually entered in the software.

Data logging with sensors is a generic experimental tool for physics, chemistry, and biology.

**Educational benefits.** The tool for data logging with sensors has many educational benefits if it is properly integrated in the science lessons. First, this tool enhances new possibilities and contexts for science experiments that might not be otherwise possible due to time constraints and technical difficulties (Barton, 2004; Newton & Rogers, 2001). This increases access to real-life phenomena, facilitates new classroom experiments, and allows measurements in the field. Second, the tool enables collecting, recording, and representing of many data and even repeating this process several times *in short time* (physical world). Consequently, pupils will have time in the classroom to design the experiment, interpret data, and/or explain relationships (theoretical world).

Third, the “real-time graphing” feature of the data-logging tool stimulates pupils to move back and forth between the physical world and the theoretical world. For example, a pupil walks in front of a motion sensor, and immediately the software shows in the graph her or his position and/or velocity in real time. By observing the pupil walking and the graph showing up at almost the same time, other pupils in the class can easily realise the connection between the motion of their classmate and the kinematics concepts. According to Brasell (1987), this immediacy between the phenomenon and real-time graphing of data stimulates pupils’ conceptual understanding, and this feature is critical for both understanding and motivation. Sokoloff, Laws, and Thornton (2007) showed research evidence that the use of the tool for data logging with sensors in a laboratory curriculum (i.e. RealTime Physics Mechanics) improved pupils’ understanding of dynamics concepts, and the retention of the concepts by those pupils was excellent.

Last but not least, the incorporation of the data-logging tool enables pupils to participate in aspects of scientists’ experimental inquiry, considering that the data-logging tool is similar to those used by scientists. According to Ellermeijer, Landheer, and Molenaar (1996), once pupils get used to the data-logging tool, they can decide and reflect at any time about what to measure, how to calibrate, and what readings should be taken. This shows that such participation in authentic inquiry with the data-logging tool will stimulate pupils to comprehend scientific inquiry.

*c) The ICT tool for video measurement*

**Characteristics.** The ICT tool for video measurement enables pupils to conduct experiments in which, for instance, position and time data of a moving object, registered in a digital video, are collected in the successive video frames by mouse clicking. Among different software, there are common steps to gather real-life data from a video. First, the user has to
define the video scale, time calibration and coordinate system. The video clip is scaled by specifying which distance on the video screen corresponds to which actual distance (e.g. 1m viewed in the video frame in Figure 2.4). A video is a collection of rapidly displayed pictures called video frames. The time interval between two successive frames shown in the software is calibrated by entering the actual frame rate of the video (i.e. how many video frames were taken in a second as the video was recorded). Next, the user moves the cursor over the video screen to locate the point(s) of interest (e.g. a baseball) and then click to store the first video point (i.e. first coordinate and time data). The video clip automatically advances to the next frame, and then the user continues clicking on the reference point. This procedure with the software is repeated until the user obtains a desired number of data points.

Some software (e.g. Coach) allows automated tracking of the movement of objects and enables collection of different video points in a single video frame. Like the data logging with sensors, during the manual measurement and automated tracking from a video, the collected data are simultaneously displayed in a diagram or table (real-time graphing) (Figure 2.4). Other dynamics quantities such as velocity, acceleration, momentum, kinetic energy, force can be numerically computed based on the collected data. Finally, collected and computed data are analysed and processed further by the software. Video measurement is mostly limited to movement, so it is mostly used in physics.

![Figure 2.4. Screenshot of an experimentation activity facilitated by the video-measurement tool; in this case, position and time of a baseball is collected from a high-speed video and displayed in the graph and table by the software. The dotted cross in the graph indicates that the scan feature of the software is activated. In this illustration, the data point (-0.7284m, 0.1498s) on the graph and the table is scanned, and the video advances to Frame 74, which shows the corresponding position of the baseball.](image)

**Educational benefits.** The tool for video measurement has much added value if it is incorporated appropriately in school science. First, like the data-logging tool, video measurement creates new possibilities and contexts for experimentation activities. With the video-measurement tool, the teacher can bring real-life, attractive scenes of motion into classroom activities that show pupils the relevance of science concepts and theory in everyday life (Heck, 2009; Zollman & Fuller, 1994). Such realistic scenes of motion can be quite
ordinary (e.g. basketball shots, amusement-park rides, dancing) or unusual (e.g. car crashes, jumps on the Moon, rocket launch). With high-speed videos (i.e. up to 1200 frames per second), the teacher and pupils can quantitatively explore many more situations of realistic motions (e.g. multi-dimensional collisions between billiard balls, gun recoil) that would be mostly impossible to investigate with traditional instruments and even with sensors for school science. Additionally, the video-measurement tool can serve as a cost and time effective instrument for the school laboratory, which might replace rulers, timers, photo gates, and motion sensors in motion-related experiments.

Second, the tool enables the collection and representation of many video data from different realistic situations in a short time (physical world). Consequently, pupils will have time in the classroom to interpret data and/or explain relationships (theoretical world). Third, the “real-time graphing” and “scan” features of the video-measurement tool stimulate pupils to think back and forth between the physical and theoretical worlds. This becomes more likely as images of these two worlds are shown in the same software interface (Figure 2.4). When pupils scan a particular data point in one of the graphs, the corresponding video frame, where the data were collected, displays simultaneously. This feature enables pupils to identify events during the realistic situation (physical world) and connect them to abstract representations in the graph (theoretical world). This results in pupils’ deeper understanding of the motion and related kinematic concepts (Beichner, 1996; Gröber, Klein, & Kuhn, 2014).

Last but not least, the incorporation of the video-measurement tool makes it possible for pupils to exercise experimental inquiry practices similar to those of biomechanics and movement-science scientists (Heck, 2009; Kearney & Treagust, 2001; Laws & Pfister, 1998). Pupils can participate in many aspects of experimental inquiry using video measurement. For example, formulating problems; designing the scenario and setup for appropriate video recording by a webcam, a smartphone, or a video camera; calibrating time and scale of the video; defining from which frames to get data and with which techniques to collect data; and processing and interpreting the collected video data.

**d) The ICT tool for dynamical modelling**

**Characteristics.** Modelling has different meanings for different communities; depending upon the context in which it is discussed. In this present research, the term “modelling” will refer to computational, dynamical modelling that is a tool used by scientists in many different fields (e.g. science, technology, economics, sociology) to describe, explain, and predict complex dynamical systems. It helps to understand a system’s structure, the interaction between its objects, and the behaviour it can produce. Many of such systems can be built as models on the computer, which can carry out many more simultaneous calculations than human mental models and which can enable solution of differential equations. These differential equations cannot be solved with secondary school mathematics.

The ICT tool for dynamical modelling provides the teacher and pupils with possibilities to be engaged in the modelling process in science: “analyse a situation in a realistic context and reduce it to a manageable problem, translate this into a model, generate outcomes, interpret these outcomes, and test and evaluate the model” (van Buuren, Uylings, & Ellermeijer, 2010, p.112). First, a realistic context (e.g. a tennis ball bouncing on the floor) is analysed and simplified to be manageable by ignoring realistic effects or situational factors
(e.g. the ball moving vertically without rotation, air resistance, and aerodynamics effects); the stripped-down, mental model is then translated into a computational model. Next, the computational model is constructed by graphical elements: state variables (e.g. height, velocity); in- and out-flows of state variables (i.e. rates of change); auxiliary variables; constants (e.g. acceleration due to gravity); events (e.g. bounce) that provoke discrete, instantaneous changes of state variables; and relations that are visualised by connectors between variables, constants, events (Figure 2.5) and are specified by mathematical formulas.

As the model is executed, differential equations behind the model are automatically solved by numerical iteration methods and so result in values of variables as a function of time. To interpret these modelling data, the modeller needs to choose relevant representations of the resulting values of variables such as a) graphs that show more explicit, comprehensible relationship between variables; b) animations that visualise behaviours of modelled objects. To validate the model (i.e. evaluating its descriptive, predictive, and explanatory quality), the modeller compares modelling outcomes with their counterparts in the physical world (i.e. standards, measured data, empirical graphs).

![Figure 2.5. Screenshot of a modelling activity facilitated by the modelling tool: bouncing of a solid, rubber ball is modelled, and the modelling result is compared with data obtained from video measurement of the bouncing ball (Heck, Ellermeijer, & Kedzierska, 2009). The graph shows the modelling result (solid curve) and the measurement (dots) for height versus time.](image)

There are different ways to represent variables and relationships behind a dynamical model, including a) the stock and flow mode\(^1\) (graphical representation) and b) text-based modes, using equations or a textual representation. For the ICT in IBSE course, we confined ourselves to graphical modelling with a stock and flow representation of variables and relationships among these variables. This was because the stock and flow representations stimulate pupils to focus on qualitative relationships (theoretical world) and connections of these to the realistic situation (physical world) rather than mathematical equations or programming syntaxes.

**Educational benefits.** First, the modelling tool holds the potential to enlarge possibilities for pupils’ theoretical inquiry of realistic, dynamic phenomena (e.g. motion with

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\(^1\) Within modelling environments like Coach, PowerSim, and Stella, dynamical modelling is based on the stock and flow approach, which was developed by Forrester (1961, 1994) (as cited in Heck, 2009, p.168).
air resistance, charging and discharging capacitors, combustion of carbon monoxide, and chemical equilibrium). These phenomena are difficult to describe with school mathematics but relatively easy to model with software (Heck, 2009; Velanova, Demkanin, Gergelova, & Demkaninova, 2014). There are different patterns in which pupils can move back and forth between the theoretical and physical worlds and so learn with the modelling tool. For example, pupils run a given model (e.g. a parachute jump with air resistance) to understand a phenomenon and/or explore its structure to gain insight into interactions between the model elements. Based upon their understanding, pupils can also make a small change to a given model, try out various modelling ideas, and then evaluate if the revised model describes the phenomenon better. For example, “unfortunately, the parachute does not open right away. Therefore, there is first free fall for two minutes and then fall with air resistance while the parachute already opens”. With a certain mastery of the modelling tool, pupils may construct a new model from their mental model of the realistic phenomenon and validate the model by comparing modelling outcomes with experimental results. Patterns for teachers to prepare a lesson, using the modelling tool are similar; the teacher might use a ready model, modify it a bit, or develop a new model. See Chapter 4, Section 4.3.3 where we describe Dutch participants’ ICT in IBSE try-outs, which actually realised different patterns of inquiry teaching with the modelling tool.

Second, the software allows importing measured data and graphs to the modelling activity. This enables simultaneous observations of the modelling graph (i.e. an outcome from the theoretical world) and the experimental graph (i.e. an outcome from the physical world) in the same diagram (Figure 2.5). It is convenient for pupils to compare these outcomes of the two worlds. If the modelling result does not fit real data, then pupils can adjust the model (e.g. changing parameters, adding variables, correcting relationships), execute it again, and compare new modelling results with the real data. The modelling tool enhances opportunities for many rounds of thinking back and forth between the theoretical and physical worlds.

Last but not least, the incorporation of the modelling tool enables pupils to a) get used to modelling as a scientific tool in computational science (doing science with computer), b) appreciate what modelling is as a way of thinking and c) understand how important it is in science. Heck and colleagues showcased pupils’ research projects (i.e. yo-yos, bouncing balls, alcohol metabolism, beer foam) in which pupils could build models from simple to more complex (i.e. progressive modelling approach) by incorporating more factors aimed at better matching between the model and reality (Heck, 2007, 2009; Heck, Ellermeijer, & Kedzierska, 2009).

e) Data processing and analysis: generic components of the three tools

Generated from the model or collected from the experiment or the video, numerical data can be then quickly transformed into more comprehensible, graphical representations: graphs, tables, and animations. If such representation forms are arranged in advance, then pupils can see, for example, how empirical graphs appear (i.e. real-time graphing) or how animated objects move during the measurement or generation of data.

Additionally, just requiring simple manipulations, the software provides pupils with many possibilities for elementary analysis such as scan, slope, area and further processing such as a) fitting or modelling the data with analytic functions (e.g. function fit); b)
integrating, differentiating data; and c) displaying Fourier transforms of the data (Sokoloff et al., 2007; Heck, Kedzierska, & Ellermeijer, 2009). Moreover, swift analysis and processing with three tools save time on labour intensive, repetitive tasks (e.g. drawing graphs) and so allow pupils to focus on inquiry skills like interpreting data, inferring relationships, and testing different assumptions, which are otherwise impossible due to time constraints. These features of data processing and analysis crucially add to specific characteristics of the three ICT tools. This makes of each of the ICT tools an authentic platform where pupils can easily move back and forth between the physical and theoretical worlds within the classroom time to generate or validate knowledge of science.

f) Rationale behind the selection of the three ICT tools

Amongst ICT applications in science education, we selected the data-logging, video-measurement, and modelling tools for the ICT in IBSE course, because these constructional tools can stimulate inquiry by pupils. The proper use of these tools enhances opportunities and time for pupils’ generation and validation of knowledge in the classroom. These meaningful opportunities and sufficient time enable pupils to move back and forth between the physical and theoretical world within the inquiry process. In other ICT applications, these possibilities and benefits do not happen; they are educational tools for rather different aims and usually do not use real data collected by pupils.

Moreover, we selected the three ICT tools because they match with the curriculum demand. This reason stems from the implication that teacher education initiatives should be directly focused on curricula, materials, and tools that teachers are using for instruction (Cooper, 2009). In particular, already for a long time, science curricula have included laboratory activities. Together with a widespread integration of ICT in schools, there have been more and more school curricula that incorporate data logging with sensors in the science laboratory. Furthermore, in recent years, learning about modelling and learning to model have become explicit goals of science curricula in many countries (e.g. the Netherlands, the United States, Germany, and the United Kingdom). The current framework for science education in the United States (NRC, 2012), for example, stated that

Curricula will need to stress the role of models explicitly and provide students with modelling tools so that students come to value this core practice and develop a level of facility in constructing and applying appropriate models” (p.59).

In addition, modelling is now included in the Dutch Physics curriculum for the pre-university track in secondary schools. Recently, a learning path to achieve modelling skills has been developed for the Dutch lower secondary physics curriculum. This learning path is completely integrated into the curriculum and has been tested in school practice (van Buuren, 2014). The use of other ICT applications like tutorial courseware, simulation applets can be helpful in the lessons but is not included in curriculum requirements.

g) Pedagogical considerations for our ICT in IBSE course

Integration of ICT with inquiry practices. For the ICT in IBSE course, we confined ourselves to the three tools: data logging with sensors, video measurement, and dynamical modelling and the use of these tools to stimulate inquiry by pupils through experimentation or
modelling activities. In particular, the participants had to operationalise opportunities for practising inquiry skills within the ICT-enhanced experimentation/modelling activity (i.e. lesson plan) and then guide pupils to consciously exercise such skills (i.e. lesson try-out). This integration of ICT with IBSE is not trivial. Research has shown pupils’ perception that doing experiment means manipulating equipment and software but not manipulating ideas (Abrahams & Reiss, 2012; Chang & Lederman, 1994; Wilkenson & Ward, 1997). Use of ICT has a tendency to make pupil activities more prescriptive while we want to make them more investigative. We aimed at the shift from manipulations of equipment and software to manipulations of ideas. For example, if the teacher just uses the sensor measurement for the practical work in which pupils follow the given worksheet with step-by-step instructions to set up the experiment, collect and analyse data to validate Boyle's law, then the data-logging tool does not add much to IBSE. It does not stimulate pupils’ inquiry so much. If the pupils themselves have to design a verification experiment and carry it out according their own design, then the pupil exercises a wider array of inquiry skills, so not following a recipe.

Introduction to the ICT tools and evaluation on awareness of educational benefits. The description of characteristics and possibilities of the three ICT tools was included in introductory slides, which were used as support materials for course participants. In the first live session, the course instructor would use these slides and introduce the participants to these tools. Additionally, after the course, the participants were asked to enumerate educational benefits of the ICT tools. The answers would be then compared with the benefits of the ICT tools as pointed out in this section. The comparison was to evaluate if the participants were aware of added value of the ICT tools (i.e. one of the course objective).

2.1.3 Integration of ICT into IBSE: challenges to pupils and teachers

Even without ICT integration, proper implementation of IBSE activities is still a problem for teachers. In this section, we identify particular challenges to pupils and teachers in inquiry-based teaching and learning without and with ICT. Based on understanding of these challenges, we propose a) realistic and worthwhile requirements for the ICT in IBSE try-out within our ICT in IBSE course and b) a long-term vision that stimulates participants to continue applying ICT in IBSE after the course.

a) Challenges to pupils

Authentic inquiry and intrinsic problems of pupils. Pupils’ authentic inquiry in the classroom should be similar to, but cannot be the same as those of scientists, because interests, background knowledge, and motivations of pupils are enormously different from those of scientists (Edelson, 1998). “Real” authentic inquiry is open-ended and requires a solid discipline-knowledge base. As Ogborn (2014) claimed, real inquiry takes some years and requires scientists “full critical attention”, whereas “replicated” inquiry in the classroom is often intended for very limited time (i.e. half an hour) and relies on pupils’ “intuitive responses”. These responses “will most often be wrong or misguided, yet seem good to them, and be difficult to counter” (p.42). Reviewing a number of studies that empirically examined the inquiry learning process, de Jong and van Joolingen (1998) identified “intrinsic problems” of pupils in inquiry learning. These problems are related to hypothesis generation, design of
investigations, interpretation of data, and regulation of learning. Consequently, IBSE might generate a heavy cognitive load for pupils (Kirschner et al., 2006).

**ICT in IBSE and extra cognitive load for pupils.** Integration of ICT into IBSE might add extra cognitive load for pupils, considering that most pupils lack experience of handling the ICT tools. For example, about the modelling tool, concepts involved with dynamical modelling and the modelling process are abstract and rather complex. Sins, Savelsbergh, & van Joolingen (2005) reported that pupils as novice modellers often encounter characteristic problems in regard to the task perception, the content addressed, and the tools used. Furthermore, the use of ICT tools as an integral component of scientific investigation involves pupils in rationalising what they are doing with software and equipment. It also involves pupils in making sense out of what they have observed or measured by linking these to hypotheses, concepts, and theory. Such activities require much higher cognitive load than those that just require pupils to observe and record some features of an event or process, demonstrated by teachers using ICT tools (Abrahams & Millar, 2008). Under such high cognitive load, pupils will either drop out of the ICT in IBSE activity or try to just survive by carrying it out in a procedural way with minimum efforts of minds-on inquiring and meaning making (van Joolingen, de Jong, & Dimitrakopoulou, 2007).

**b) Challenges to teachers**

**Heavy cognitive load for teachers.** Teachers are often too much focussed on knowledge goals (Abrahams & Reiss, 2012). In inquiry teaching, they find it difficult to elicit pupils’ ideas about the research questions, to guide pupils in planning, executing investigations and analysing, interpreting data, and to manage pupils’ independent learning at different paces (Davis et al., 2006; Hofstein & Lunetta, 2004). ICT provides innovative tools for IBSE, but the use of these tools will “further complicate the complex web of overlapping factors, which characterise pedagogical thinking involved in planning and executing lessons” (Rogers & Twiddle, 2013, p.229).

Effective ICT integration assumes that teachers have to learn possibilities of the ICT tools for their subject, acquire skills to operate the software and hardware, and get used to troubleshooting technical problems. More importantly, teachers need to adapt and improve their pedagogical knowledge to be able to design suitable ICT in IBSE activities and engage pupils in implementation of such activities in the classroom. This demand regarding the ICT integration adds extra load to cognitive load of IBSE teaching. Such cognitive load will be even higher for student teachers (i.e. participants of the Dutch ICT in IBSE course) due to classroom management problems. Van den Berg (2014) described this as follows:

Many of the nice teaching methods encountered in the teacher education programme do not work yet in the first year of teaching due to classroom management problems. Novice teachers then tend to fall back to a very limited set of traditional and boring methods of teaching (p.25)

**Inquiry teaching versus prescriptive instruction with ICT.** Pupils need sufficient instruction and practice time in order to handle laboratory equipment in the classroom. Recipes like "do this, then do that" might be the fastest and most convenient way in helping pupils to get over hurdles in manipulating equipment within a limited time, but it hinders pupils’ minds-on inquiring and meaning making. Research on practical work often uses the “cookbook” metaphor to describe this prescriptive instruction (Figure 2.6). Considering the
ICT integration, extra instructions needed to handle the necessary software might further reinforce the prescriptive nature of ICT-enhanced experimentation/modelling activities. These instructions can unintendedly come to dominate the activity, although there are practical ways to get around this. For example, after a cookbook phase for learning to manipulate the tools should come an inquiry phase in which pupils themselves have to make decisions on how to use the new tools in their investigations.

Figure 2.6. In the photograph (b), a pupil was following a cookbook instruction (a) to set up the experiment using sensors and the computer.

**Limited preparation time and limited curriculum time.** In many countries including Slovakia and Vietnam, teachers are pressed to teach all of the content standards within a tightly structured, explicitly expressed syllabus (Woolnough, 2001). In the Netherlands, the school science curricula are rather overloaded with standardised requirements, too; except that the way to attain these requirements is mostly left open to the teacher. In such constrained circumstances, teachers tend to get through the content (Bencze & Hodson, 1999) rather than engaging pupils in investigations with the ICT tools. This is because these investigations require ample time and aim at not only conceptual learning but also other goals. Incorporating the ICT tools in school science might add extra problems to time-constraint situations, considering that teachers need extra time, effort, and/or training to learn to handle the ICT tools and to practice their use. Logistics of organising the use of hardware and software cause extra preparation time for teachers. The constraints on preparation time and curriculum time can be a factor explaining for the fact that: although the ICT tools have many innovative features that stimulate pupils’ authentic inquiry practices, really authentic inquiry learning is limited to few special projects, for example in Dutch schools, once in junior secondary and once in senior secondary.

c) Pedagogical considerations for our ICT in IBSE course

The challenges to pupils and teachers led us to the conclusion that integration of ICT into IBSE needs sufficient time to be faithfully implemented. An actual impact of ICT in IBSE teaching on pupils needs both a longer period of time and consistent incorporation of ICT in IBSE in regular teaching. Also considering the fact that a) the classroom try-out within the course would be time limited, and b) it would be one of the first ICT in IBSE lessons the participants would ever teach, we scaled down the complexity of the ICT in
IBSE try-out to a suitable level of cognitive challenge. Importantly, the first session of the course had to a) set out a vision of sustainable incorporation of ICT in IBSE in teaching practice and b) make the participants aware that the try-out within the course was just a start of such long-term vision and ambition.

**Realistic and worthwhile requirements for the ICT in IBSE lesson.** Based on Van den Berg’s approach (2013), we defined requirements for the ICT in IBSE lesson as follows:

Participants were required to limit complexity of the ICT in IBSE lesson by a) choosing suitable topics (incl. conceptual goals) and b) focusing sharply on a few inquiry skills (Table 2.3), leaving out others, and using direct instruction when needed.

The participants were required to focus more on skills that a) stimulate pupils to think back and forth between the theoretical and physical worlds than skills that mostly require manipulations of equipment and software and b) fit pupils’ prior experience to avoid cognitive overload for pupils.

In the classroom, participants were required to:
- scaffold pupils’ exercises of intended inquiry practices by guiding these explicitly;
- offer pupils appropriate supports that are just enough and just in time, avoiding the reduction of the inquiry process to cookbook instructions.

**A long-term vision.** According to Van den Berg’s (2013) suggestions, after the course and throughout the whole school year, the participants should carry out more ICT in IBSE try-outs that focus on different inquiry skills in different contexts. After one to two years, the participants and their pupils would probably cover the full range of inquiry skills (Table 2.3) and become competent in handling the ICT tools.

**Building confidence in teachers.** We stimulated and supported each participant to design a reasonable ICT in IBSE lesson plan, implement it faithfully in the classroom, and evaluate the try-out experience. In particular, we first left ample options for the participants to decide which would best suit their teaching conditions and interest (e.g. which inquiry components to focus on; which ICT tool was used to facilitate inquiry practices; what topic, activity, grade level, and context of the lesson). Second, we provided the participants with forms for designing and self-evaluating the ICT in IBSE lesson (see Section 3.1.4).

Third, we suggested necessary revisions of the participants’ lesson plan before its try-out, for example, preparing for pupils with prerequisite ICT skills before the try-out; leaving out certain objectives that are too ambitious for the timing and/or for the level of pupils; and

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2 Van den Berg’s (2013) approach is primarily aimed at effective inquiry learning of pupils. However, it is also relevant for teachers in IBSE teaching, even more relevant as IBSE teaching is integrated with ICT.

3 Accordingly, the participants probably arranged just a part of the lesson with inquiry practices, and other parts with direct instruction.

4 For example, defining variables of an experiment/model and how each variable will be measured or modelled; explaining experiment/modelling results (i.e. categories 1.3a, 1.3b, 3.5 in Table 2.3). These inquiry components involve manipulation of ideas rather than only manipulation of equipment and software (i.e. categories 2.1, 2.3 in Table 2.3).

5 The inquiry components that really count for the cognitive load are those that are either difficult or new for the pupils. For example, formulating a tentative answer to the research question (Category 3.3, Table 2.3) may add to the cognitive load when pupils have little experience. It may not count as cognitive load when pupils have much experience with hypothesis construction.
adding certain questions that promote pupils to think back and forth between the theoretical and physical worlds. Through the ICT in IBSE try-out, the participants would recognise varied aspects of ICT in IBSE and attain teaching experience. Finally, in the last live session, we provided opportunities for participants to make sense of these practical aspects and experiences through reflection and discussion and so generate their understanding of ICT in IBSE teaching. This is intended as a step-up for participants’ future professional growth considering integration of ICT into IBSE. After the ICT in IBSE course, the participants might feel not everything succeeded, but they would believe in their ability. They would know how to learn further, be capable of doing that, and desire to teach more ICT in IBSE lessons after the course.

2.2 Integration of ICT into IBSE: teacher knowledge and the ICT in IBSE lesson

2.2.1 Frameworks of teacher knowledge and knowledge integration

In this section, we connect the concept of Pedagogical Content Knowledge (PCK) to teachers’ knowledge demanded by IBSE teaching. Regarding the ICT integration, we use a knowledge integration framework. This framework matches well with the Technological Pedagogical Content Knowledge model (TPCK), which considers technology as new knowledge integrated in existing PCK (e.g. IBSE). At the end of the section, we clarify pedagogical considerations for our teacher-education course on integration of ICT into IBSE.

a) Pedagogical content knowledge

Pedagogical content knowledge. The teaching profession requires from science teachers the ability to design and implement activities that foster pupils’ conceptual understanding and inquiry practices. Subject-matter knowledge also called content knowledge (CK) is certainly needed, but just CK is not enough for teachers to handle the cognitive complexity of inquiry-based teaching of science (see Section 2.1.3). In addition, this knowledge cannot simply be “handed over” to pupils (Rogers & Twidle, 2013, p.234). Teachers need another type of knowledge that enables them to transform subject matter into different forms of representation, which pupils can generate, validate, and learn. This category of knowledge is termed as Pedagogical Content Knowledge (PCK). The concept of PCK was first introduced by Shulman in his inspiring article of 1986 as follows:

Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible for others (p.9).

Characteristics of PCK. The pedagogy of science instruction is not a simple combination of general pedagogy and subject matter. Rather it involves transformation of subject matter knowledge, general pedagogical knowledge, and knowledge of context (incl. curriculum, pupils, and equipment) into viable instruction (Abell, 2008). Consequently, in order to master PCK, the teacher must a) interpret the subject matter, b) find multiple ways to represent it; c) adapt instructional strategies and materials to teaching conditions. More
importantly, these efforts must have actual effect on pupils’ learning. Obviously, much of teachers’ PCK is craft knowledge, built through on-going try-outs of their PCK in the classroom (McCrory, 2008). PCK, therefore, can be considered as teacher’s practical knowledge (Van Driel, Verloop, & de Vos, 1998).

Through experience, a teacher develops certain ways of representing and formulating a subject, but she or he is not always explicitly aware of this, so part of a teacher’s PCK is tacit knowledge. PCK is “uniquely the province” of the teachers (Shulman, 1987, p.8). Furthermore, according to Van den Berg (2014), PCK should be generative; “generative” in the sense that comprehending first PCK will open the eyes of teachers, lead them a) “to be much more observant and discover more PCK” (p.26) by themselves in the classroom and b) to access a) tacit PCK of teacher educators and colleagues and b) PCK behind existing instructional materials and textbooks.

**PCK of IBSE teaching.** In IBSE teaching, the teacher engages pupils in the process of generating or validating subject-matter knowledge. Original subject matter is often abstract, rather complex, and difficult for pupils to process. PCK of IBSE teaching involves teachers’ ability to transform original content knowledge into representations that pupils are able to manipulate, generate, validate, and comprehend. It also involves teachers’ ability to a) design inquiry activities and b) engage, guide, and support pupils in such activities. These are crucial manifestations of a teacher’s PCK of IBSE teaching.

![Figure 2.7. TPCK model of technology integration into content-specific, context-specific teaching. Three key knowledge domains (i.e. CK, PK, & TK) overlap, leading to four more domains of interrelated knowledge (PCK, TPK, TCK, and TPCK) (adapted from Koehler & Mishra, 2005).](image)

**b) Integration of technological knowledge into PCK**

Technology, as integrated into school science, can supplement teacher’s PCK because it generates new forms of representation for conceptual learning and stimulates new opportunities and contexts for inquiry practices (Newton & Rogers, 2001). Koehler and
Mishra (2005) built on Shulman’s formulation of PCK (1986) and added technology as a key component to the framework of *technology integration into content-specific teaching*, named Technological Pedagogical Content Knowledge (TPCK) (Figure 2.7).

Like PCK, TPCK is not a simple combination of technological knowledge and existing PCK. Rather, the TPCK model represents a *thoughtful interweaving* of three key knowledge categories: Content, Pedagogy, and Technology. This interweaving involves interrelated knowledge domains (i.e. TPCK, PCK, TCK, and TPK). For example:

- knowledge about technology-enhanced representations (e.g. real-time graphing, model-driven animations) of science concepts and technology-enhanced analysis (e.g. scanning, function fit, Fourier transform) of data (TCK)
- knowledge about possibilities of using available software and laboratory equipment (incl. sensors, data loggers) to teach certain concepts (TPCK).

c) Knowledge-integration framework

The formulation of the TPCK model is consistent with a knowledge-integration framework that Gerard et al. (2011) recommended for teacher education initiatives on technology integration. This framework emphasises building on “the repertoire of ideas” held by the teacher as a learner, including four main steps to be taken by the teacher educator (Gerard et al., 2011, p.411):

*Step 1.* Eliciting initial views (e.g. PCK of IBSE teaching)
*Step 2.* Adding new ideas (e.g. Integration of ICT with inquiry practices - TPCK)
*Step 3.* Enabling teachers to use evidence from pupils’ work to distinguish among new ideas and their existing views
*Step 4.* Engaging teachers in an ongoing process of reflecting on, refining and integrating new ideas into their existing practices

Like PCK, TPCK is often tacit, practical knowledge. Therefore, ongoing classroom try-outs of technological integration (e.g. ICT in IBSE) as the fourth step of the knowledge-integration framework will be crucial for teachers to be able to generate their TPCK of ICT in IBSE teaching. According to Rogers (2013, p.246), “the classroom is a vital test-bed for the development and refinement of pedagogical practice and, as ever, the response of students is the ultimate educator for teachers.” Through the classroom try-out, teachers by themselves will figure out, for example:

- which inquiry practices to be focussed on in a certain context;
- how to design suitable ICT in IBSE activities, using the ICT tool;
- how to guide pupils to exercise inquiry practices within ICT in IBSE activities;
- how to refine their instruction based on pupils’ feedback in the classroom.

According to Donnelly et al. (2014, p. 593), cumulatively gaining such practical knowledge, teachers “become prepared to enhance inquiry opportunities across the curriculum”. However, this takes teachers several years of consistent and intensive efforts for ICT in IBSE incorporation in the classroom (Gerard et al., 2011). After that, much PCK of the teachers regarding ICT in IBSE teaching turns into explicit and conscious knowledge, so becomes
generative. *This perspective is in line with our long-term approach and vision for dealing challenges of ICT in IBSE teaching, which are discussed in Section 2.1.3.*

d) Pedagogical considerations for our ICT in IBSE course

The ICT in IBSE try-out as the core of the course. The above literature study led us to a conclusion that much TPCK of ICT in IBSE teaching is craft knowledge, emerging from classroom practice. The classroom try-out would provide participants with opportunities a) to transform their knowledge regarding different domains (i.e. subject matter, PCK of IBSE teaching, ICT) into viable ICT in IBSE lessons and b) to generate their practical TPCK of ICT in IBSE teaching. This conclusion reinforces the choice of the *ICT in IBSE try-out* as the main assignment of our course. Considering that the ICT in IBSE try-out would be a first time experience for most participants, we had to prepare proper conditions during the course for them to make the most of their try-outs, especially positive motivations regarding ICT in IBSE integration.

Application of the knowledge-integration framework. From teaching experiences and preceding teacher-education courses, the participants were presumed to already have a “repertoire of ideas” about IBSE and general pedagogy (e.g. how to guide pupils in the classroom). Applying the knowledge-integration framework, we first elicited and then built on these prior ideas and views by adding TCK about the ICT tools and TPCK of ICT in IBSE teaching (i.e. second step). In particular,

- We explicitly showcased characteristics and possibilities of the three ICT tools in the first live session; especially those stimulating IBSE. For participants’ further exploration of how to make use of the ICT tools in IBSE, we introduced meaningful examples from European projects, articles, dissertations, and classroom experience.
- We provided the participants with tutorial activities and then asked them to practice these activities in the first live session and as an individual assignment to learn manipulation skills with the tools. They could consult the course instructor about technical problems in the live session and via the Internet.
- We assigned the participants to design, implement, and evaluate an ICT in IBSE lesson within the course. To support the participants, we offered a) forms for planning and self-evaluating the lesson and b) instruction and consultations regarding development and refinement of the lesson plan.

Regarding the third and fourth steps, we intended the last live session for the participants to report and reflect on their ICT in IBSE lesson, using evidence from the try-out. Through these reflections, they would refine their understandings about ICT tools and IBSE and integrate these new understandings to form their TPCK of ICT in IBSE teaching.

2.2.2 An ICT in IBSE lesson: design, execution, and evaluation

In this section, we first describe two verified instruments (i.e. LAI and PAAI) for analysing the practical activity. Next, we clarify how we adapted these instruments to define a) the 22 behavioural categories of inquiry skills within the ICT in IBSE activity and b) the framework for developing, executing, and evaluating the ICT in IBSE lesson.
Chapter 2

a) Behavioural categories of inquiry skills within the ICT in IBSE activity

Laboratory structure and task Analysis Inventory (LAI). The LAI was designed by Fuhrman, Lunetta, Novick, and Tamir and documented in Fuhrman (1978). The LAI inventory consists of 24 concrete skills of pupils demanded by a laboratory investigation and ground rules for coding. These 24 behavioural categories are divided into four subsections as follows:

1. **Planning and Design**: formulate questions; predict results; formulate hypotheses; design observation/measurement procedures; design experiments;

2. **Performance**: carry out qualitative observations; carry out quantitative observations/measurement; manipulate apparatus; record results; perform calculation; select experimental techniques; work according to own design;

3. **Analysis and interpretation**: transform results into standard forms; graph data; determine qualitative relationships; determine quantitative relationships; determine accuracy of data; discuss limitations/assumptions; generalise; explain relationships; formulate new questions;

4. **Application**: predict based upon results; formulate hypothesis based upon results; apply experimental techniques to new problems.

The LAI was used to analyse written instructions for laboratory activities of the well-known science curricula in the United States. For example, “Biological Science: An Inquiry into Life”; “PSSC Physics”, “Harvard Project Physics” (HPP), and “Modern Chemistry” laboratory manuals. At that time, all of these manuals were intended to stimulate open laboratory activities. The analysis with LAI showed that practical activities in these curricula were more prescriptive and less inquiry-oriented than claimed (Tamir & Lunetta, 1981). Although the LAI was developed to analyse written instructions for laboratory, it can also support the researcher in observing and documenting actual implementation of the practical activities in the classroom. By using the LAI, the researcher can recognise the deviation between the actual classroom practice and the written laboratory instructions. For example, the design of experiments might be short-circuited by the teacher giving a design; or formulating conclusions might be cut short by pupils copying such conclusions from a textbook or the Internet (Tamir & Lunetta, 1981). Additionally, the LAI can be used to guide teachers to modify and develop practical activities for their pupils.

**Behavioural categories of pupils’ inquiry skills within the ICT in IBSE activity.** Based on definitions of the LAI’s 24 categories, we redefined 22 categories of inquiry skills of pupils within experimentation activities, using sensor measurement or video-measurement tools. The redefinition of such categories was needed because the original LAI was for traditional laboratory, using analog measurement devices and traditional data-analysis methods with graphing paper, pencils, and handheld calculators. Furthermore, we developed a parallel LAI version to categorise modelling activities. Based on the modelling process (see Section 2.1.2), we defined categories of inquiry skills of pupils demanded by modelling activities, using the graphical, dynamical modelling tool. Next, we aligned these categories with the redefined 22 ones for experimentation activities (Table 2.3). This was because we needed the same inquiry-analysis inventory to analyse both experimentation and modelling activities. These 22 inquiry categories are observable and independent.
Table 2.3. 22 behavioural categories of inquiry skills of pupils, which can be demanded for and realised in an ICT in IBSE activity.

<table>
<thead>
<tr>
<th>In an ICT-enhanced experimentation activity, the pupils</th>
<th>In a graphical, dynamical modelling activity, the pupils</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conception, planning and design of experiment/model</td>
<td></td>
</tr>
<tr>
<td>1.1 Formulate a question or define a problem to be investigated within the activity</td>
<td>Formulate a question or define a problem to be investigated within the activity</td>
</tr>
<tr>
<td>1.2 Formulate a tentative answer to the research question (an hypothesis or expectation)</td>
<td>Formulate a tentative answer to the research question (an hypothesis or expectation)</td>
</tr>
<tr>
<td>1.3a Design of the experiment: define variables and a conceptual setup of the experiment</td>
<td>Design the model: define variables, constants, events, and relations between them.</td>
</tr>
<tr>
<td>1.3b Design the experiment: define how each variable will be observed or measured in the experiment (operational definitions)</td>
<td>Design the model: define how each variable will be modelled in the graphical, dynamical model (operational definitions)</td>
</tr>
<tr>
<td>1.3c Design the experiment: define procedures to analyse observation and/or measurement data</td>
<td>Design the model: define procedures to analyse modelling data</td>
</tr>
<tr>
<td>1.4 Predict results of the experiment based on its design</td>
<td>Predict results of the model based on its design</td>
</tr>
<tr>
<td>2. Execution of experiment/model</td>
<td></td>
</tr>
<tr>
<td>2.1 Manipulate software and/or apparatus to set up and execute the experiment</td>
<td>Manipulate software to construct and execute the model</td>
</tr>
<tr>
<td>2.2 Observe and/or measure variables</td>
<td>Determine resulting values of variables</td>
</tr>
<tr>
<td>2.3 Record observation and/or measurement data</td>
<td>Record modelling data</td>
</tr>
<tr>
<td>2.4 Make decisions or explain about experimental techniques</td>
<td>Make decisions or explain about modelling techniques</td>
</tr>
<tr>
<td>2.5 Work according to their own design (i.e. 1.3a, 1.3b, or 1.3c)</td>
<td>Work according to their own design (i.e. 1.3a, 1.3b, or 1.3c)</td>
</tr>
<tr>
<td>3. Analysis and interpretation</td>
<td></td>
</tr>
<tr>
<td>3.1 Choose representations of experimental data (e.g. tables, graphs)</td>
<td>Choose representations of modelling data (e.g. graphs, animations)</td>
</tr>
<tr>
<td>3.2 Determine accuracy and precision of experimental data</td>
<td>Determine accuracy of modelling data</td>
</tr>
<tr>
<td>3.3 Determine qualitative and/or quantitative relationships</td>
<td>Determine qualitative and/or quantitative relationships</td>
</tr>
<tr>
<td>3.4 Compare the results of the experiment to the hypothesis/expectation/prediction (i.e. 1.2 or 1.4)</td>
<td>Compare the results of the model to the hypothesis/expectation/prediction (i.e. 1.2 or 1.4)</td>
</tr>
<tr>
<td>3.5 Explain relationships by reflecting on the known theory</td>
<td>Explain modelling results by reflecting on the known theory</td>
</tr>
<tr>
<td>3.6 Discuss limitations/assumptions of the experiment</td>
<td>Discuss limitations/assumptions of the model</td>
</tr>
<tr>
<td>3.7 Propose generalizations of results of the experiment across the experiment situation</td>
<td>Propose generalizations of results of the model across the specific realistic situation</td>
</tr>
<tr>
<td>4. Applications and follow-up</td>
<td></td>
</tr>
<tr>
<td>4.1 Predict on basis of obtained results</td>
<td>Predict on basis of the validated model</td>
</tr>
<tr>
<td>4.2 Formulate new questions or define new problems based upon results of the experiment</td>
<td>Formulate new questions or define new problems based upon the validated model and the realistic situation</td>
</tr>
<tr>
<td>4.3 Formulate hypotheses for follow-up</td>
<td>Formulate hypotheses for follow-up</td>
</tr>
<tr>
<td>4.4 Apply the experimental technique to a new problem</td>
<td>Apply the modelling technique to a new problem</td>
</tr>
</tbody>
</table>
Chapter 2

In this dissertation, we use terms “lesson” and “activity” interchangeably, considering that the ICT in IBSE lesson of the course participants would be short (one unit of 45 to 60 minutes), and so include only one main activity with the ICT tool, addressing one main question. The term “lesson” is close to the daily vocabulary of teachers (e.g. lesson plan), whereas use of the term “activity” elicits a positive sense of pupils’ engagement and knowledge-construction.

b) Framework for developing, executing, and evaluating the ICT in IBSE lesson

Practical Activity Analysis Inventory (PAAI). In his booklet, Millar (2010) described the PAAI as an instrument to clarify objectives of an intended practical activity, to highlight its main features, and to evaluate its effectiveness. The framework underlying PAAI concerns development, execution, and evaluation of a practical activity. In particular, the process of developing and executing a practical activity includes four stages: 1) teacher’s objectives, 2) activity specification, 3) classroom events, and 4) learning outcomes. Evaluation of a practical activity with respect to pupil learning includes two levels:

- **Level 1 of evaluation** involves the match between what pupils were intended to do (Stage 2, Figure 2.8) and what they actually did and saw (Stage 3).
- **Level 2 of evaluation** involves the match between what pupils were aimed to learn (Stage 1) and what pupils actually achieved after the activity (Stage 4).

PAAI is specific for laboratory and pupil learning.

![Figure 2.8. Stages in developing, executing, and evaluating a practical activity (Millar, 2010).](image)

**Framework for developing, executing, and evaluating the ICT in IBSE lesson.** Based on the PAAI framework, we developed a framework for participants of the ICT in IBSE course to develop, execute, and evaluate the ICT in IBSE lesson. This framework focuses on inquiry objectives, inquiry opportunities, and evaluations of teacher teaching during the ICT in IBSE activity. In particular, we a) split the “Classroom events” stage of PAAI into Stages 3a and 3b that distinguish what teachers do and what pupils do (Figure 2.9), b) renamed the five stages, and c) refined levels of evaluation of teacher teaching. Within the ICT in IBSE course, the participants had to consider the first four stages (Figure 2.9) in designing and implementing the ICT in IBSE lesson as follows:
Stage 1. In the lesson plan, the participants had to indicate which inquiry skills in the given list of the 22 inquiry categories (Table 2.3) were included as objectives of the ICT in IBSE lesson (a few only).

Stage 2. In the lesson plan, the participants had to specify inquiry opportunities within the experimentation/modelling activity.

Stage 3a. In the classroom try-out, the participants had to offer pupils inquiry opportunities within the experimentation/modelling activity.

Stage 3b. In the classroom try-out, the majority of pupils should be engaged in the intended inquiry opportunities within the experimentation/modelling activity.

As the key requirement, the participants had to ensure the three matches among the four stages, which are aligned with the three evaluation levels as follows (Figure 2.9):

Level 1. Did the participant operationalise inquiry objectives (i.e. inquiry skills) as inquiry opportunities within the experimentation/modelling activity in the ICT in IBSE lesson plan? (The match between Stages 1 and 2)

Level 2. Did the participant offer pupils inquiry opportunities which were operationalised in the lesson plan? (The match between Stages 2 and 3a)

Level 3. Were majority of pupils engaged in inquiry opportunities which were offered by the participant? (The match between Stages 3a and 3b)

Please note that we did not measure pupil outcomes in this research.

Figure 2.9. Stages in designing and executing an ICT in IBSE activity and three-level evaluations of such activity.

Application of the framework for the ICT in IBSE course. The 22 categories of inquiry practices and the framework for participants to develop, execute, and evaluate the ICT in IBSE lesson were a) discussed with the course participants in live sessions and b) elaborated in forms for participants to design and self-evaluate the ICT in IBSE lesson (Forms 2 and 3) (see Chapter 3, Section 3.1.4). These were also used by the researcher to analyse the ICT in IBSE lesson plan and the ICT in IBSE try-out (see Chapter 3, Sections 3.4.3).
2.2.3 Patterns of ICT in IBSE lessons

a) Different patterns of inquiry-based activities

Operationalization of different sets of inquiry categories (Table 2.3) into learning sequences results in different patterns of inquiry activities. Schwab (1960) and Herron (1971) were among the first authors who classified a continuum of inquiry activities, including five patterns: confirmation, structured inquiry, guided inquiry, and open inquiry. Each pattern is coupled with a simplified model of inquiry teaching, which focuses on certain inquiry categories for pupils to exercise (Table 2.3). Other categories are left for the teacher to introduce, explain, and/or demonstrate. The continuum from highly teacher directed (e.g. confirmation) to highly student centred (e.g. open inquiry) was based on a) the level of pupils’ participation and independence or b) the degree of teacher’s guidance and control. Authors after Schwab and Herron (e.g. Bell, Smetana, & Binns, 2005; Llewellyn, 2007; NRC, 2000; Wenning, 2005) elaborated the inquiry continuum and specified examples; supplemented levels in between Herron’s levels; or restructured the spectrum and labelled each level differently.

Within the ESTABLISH project, the inquiry continuum was also redefined, including five patterns: interactive demonstration, guided discovery, guided inquiry, bounded inquiry, and open inquiry. Based on these patterns, exemplary lessons were developed and used for pre- and in-service teacher education on IBSE. Because we selected these exemplary lessons as part of support materials for the ICT in IBSE course, we applied the ESTABLISH inquiry continuum. We summarise the five patterns of this continuum as follows:

1. Interactive demonstration: the teacher is in charge of a) conducting the demonstration and manipulating equipment and software, b) interactively asking questions about what will happen (prediction) or about how something might have happened (explanation), and c) helping the pupils to reach conclusions in a scientifically correct way. The inquiry part here lies in the responses and explanations from the pupils.

2. Guided discovery: same as in the above, but in this case, the pupils carry out the experiment introduced to them by the teacher. It is the traditional pupil laboratory work, mostly in the form of cookbook laboratory or work driven by step-by-step instructions. Usually, this concerns a group activity simultaneously carried out by the whole class with a strong focus on discovering or verifying information, which is somehow known by pupils beforehand.

3. Guided inquiry: in this case, pupils work in teams on their own experiment. The teacher has identified the problem and has given a clear-cut objective: “find...”, “determine...” There is no predetermined answer and conclusions are solely based on pupil work. Pupils are given directions or extensive (pre-lab) instructions, and they are guided by multiple teacher questions in the instructions or a worksheet.

4. Bounded inquiry: same as in the above, but in this case, pupils are expected to design and conduct the experiment themselves with little or no guidance of the teacher and only partial pre-lab orientation. Example: “investigate what factors influence the period of a

6 To access the ESTABLISH exemplary lessons, use this link: http://establish-fp7.eu/resources/units.html
simple pendulum”. The research problem to be solved is given to them by the teacher, but they have the responsibility for designing and conducting an experiment.

5. **Open inquiry**: within a given context, pupils are expected to propose and pursue their own research question(s) and experimental design.

From to pattern 1 to pattern 5, pupils’ participation and independence increase, in reverse, the teacher’s guidance and control decrease.

*b) Pedagogical considerations for our ICT in IBSE course*

Obviously, such a continuum is not as discrete as presented above, but it serves as a tool to analyse the ICT in IBSE lesson regarding the *hierarchical level* of pupils’ participation and independence and the teacher’s guidance and control. The analysis criteria involve the four analysis questions as presented in Table 2.4. Different patterns of ICT in IBSE try-outs would be discussed at the end of the course. The participants would learn to distinguish practical ICT in IBSE patterns from each other. This awareness and experience would be a step-up for the participants’ future incorporation of ICT in IBSE in teaching practice.

*Table 2.4. Analysis criteria to categorise the ICT in IBSE lesson to the five inquiry patterns.*

<table>
<thead>
<tr>
<th>Inquiry patterns</th>
<th>Is the problem given to pupils?</th>
<th>Is the procedure given to pupils beforehand?</th>
<th>Is the answer known by pupils beforehand?</th>
<th>Does the teacher manipulate equipment?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interactive demonstration</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>2. Guided discovery</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>3. Guided inquiry</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>4. Bounded inquiry</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>5. Open inquiry</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

2.3 The ICT in IBSE course: pre- and in-service teacher education

2.3.1 A teacher’s career trajectory and role of teacher education

*a) General role of teacher education*

Qualification and experience of teachers are key factors in determining pupil achievement (Darling-Hammond, 1997). It is dependent upon how teachers have been educated as a student teacher (Cooper, 2009) and on their experiences in the first years of teaching. Learning to teach science, furthermore, occurs over a developmental *career trajectory* from pre-service teacher education to retirement (NRC, 1996). During this trajectory, the teaching environment changes quite often with new technology and strategies for teaching and learning; new educational policy; and new top-down pressures to perform. Many teachers get stuck in a pattern somewhere along the way. To transform, grow, and
remain effective, teachers, therefore, need continuous and effective support through various initiatives for professional development (PD). In this dissertation, we use the terms “teacher professional development” and “in-service teacher education” interchangeably.

b) A teacher’s career trajectory and positions of Dutch, Slovak, and Vietnamese participants of the ICT in IBSE course

According to Steffy (1989), a teacher’s career trajectory includes the following progressive phases: novice, apprentice, professional, expert, distinguished, and emeritus. The novice phase (also called pre-professional phase) begins with the first practicum experiences, then teaching assignments and internship as part of the teacher education programme. The apprentice phase (also called threshold phase) begins when teachers take responsibility for planning and implementing classroom activities on their own. It includes the induction period and extends into the second or third year of teaching (Steffy & Wolfe, 2001). Transition of knowledge and skills gained from pre-service teacher education to fulfilling the professional demands is always challenging and strenuous in the first years of teaching. It is described in studies in many different countries as a transition shock (Beauchamp & Thomas, 2009; Van den Berg, 2014; Brouwer & Korthagen, 2005; Veenman, 1984). Teachers who participated in our ICT in IBSE course in the Netherlands were in these beginning phases of the career trajectory.

The professional phase concerns the growth into the profession of most in-service teachers, who were able to pass the hurdles of the first phases. These teachers master basic tools (e.g. ICT and laboratory) and strategies (e.g. IBSE) to design and implement classroom activities. Having more lessons faithfully and effectively implemented, teachers in this phase gain more confidence and contentment. Part of this group of teachers keep growing in motivation and ability and reach their peak performance during the expert and distinguished phases while others do not go beyond the professional phase. In accordance to Rolls and Plauborg (2009), throughout the teaching career, critical incidents might occur and cause periods of crisis, stagnation, and decline. Factors such as ambitions for promotion, demanding curriculum reforms (e.g. new technology and strategies for teaching and learning), and poor pupil achievement can significantly affect working attitudes of teachers. Approaching to retirement (i.e. emeritus phase or phase of winding down), teachers often look back over their careers and reflect upon whether they have achieved what they expected. Participants of the ICT in IBSE course in Slovakia were teachers with diverse experience from first years to 33 years of teaching (almost retired). Vietnamese participants of the course varied from just graduated from Bachelor pre-service teacher education to having taught for 9 years.

c) A model of progression with ICT integration and consideration for our ICT in IBSE course

Concerning teachers’ professional growth in regard to their integration of ICT in science education, Rogers and Twidle (2013) proposed a metaphor: “professional development as a journey” in which the starting points for individual teachers might be different” (i.e. non-user, adopter, adapter, innovator, creator/mentor, p.242). Non-user teachers may have general computer skills but never teach with ICT tools in the classroom, whereas adopter teachers make use of ready-to-use ICT materials that fit in the curriculum. Adapter teachers adjust materials for different pupil groups and different teaching methods.
The further point in this journey is the level of innovator teachers, who develop and use the ICT materials in a different context or use them innovatively. Creator/mentor teachers create new materials and/or stimulate the use of ICT tools in the school. According to Rogers and Twidle (2013), any teacher education initiatives on ICT-enhanced teaching should aim to stimulate and assist teachers to travel further on this journey.

In Chapter 3, Section 3.4.3, we will describe how we made use of this progression model in defining the five-level scale of ICT mastery: non-user, adopter-user, adapter-user, creator-user, and expert. This scale enabled us to define the input level of the participants’ ICT mastery in order to support them sufficiently during the course and so take them further towards the higher level. It was then also used to evaluate the course objective regarding ICT mastery of participants (output level).

2.3.2 Models of pre and in-service teacher education

a) Pre-service teacher education and context of the course in the Netherlands

Pre-service teacher education is provided to an individual with certain qualifications prior to a career as a teacher. The path to become a teacher varies due to a wide range of national and institutional approaches. However, a teacher-education programme often includes two main components: a) a theoretical component with university-based courses that provide a foundation for teaching and b) a practical component with teaching practicum in the school under supervision of an experienced teacher. The professional development school is another form of teacher education. This aims to lessen the separation between the university course and the school practicum by providing great opportunities for interaction between course sessions and classroom try-outs (Darling-Hammond, 1994). As in many other countries, the Netherlands has two main tracks for science teacher education:

- A bachelor-level teacher-education degree at Universities of Applied Sciences (Hogescholen) where student teachers study both the school discipline (e.g. physics, chemistry, or biology) and education including teaching practicum in the school and which certifies graduates to teach at the lower secondary level.

- A postgraduate programme at Universities where student teachers must have a bachelor degree in the subject discipline (e.g. physics) and take at least one year of the master-level science programme (e.g. physics), before taking one year (60 ECTS7 credits) of teacher education including the school internship. All coursework is scheduled on one day per week at the university; three days are spent in the school; and one day is for individual assignments. Graduates of this programme are certified to teach at both upper and lower secondary levels.

Another option is to integrate the one-year teacher education into the 3 plus 2 year Bachelor-Master programme. The Dutch ICT in IBSE course was designed to fit in the post-graduate university-based teacher-education programme as an enrichment course (VU student

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7 ECTS stands for European Credit Transfer and Accumulation System, which is a standard for comparing the study attainment and performance of higher-education students across the European Union. ECTS credits are awarded for successfully completed studies. In the Netherlands, one ECTS credit is equivalent to 28 study hours.
teachers) or as part of the regular Physics/Chemistry education course (UvA, UU, and TU-Delft student teachers).

b) In-service teacher education and contexts of the course in Slovakia and Vietnam

The traditional view on in-service teacher education is as a series of isolated training workshops/courses in summer or scattered throughout a school year. These training courses provide teachers with experiences regarding new educational technologies or new teaching strategies (Bryan, Sederberg, Daly, Sears, & Giordano, 2012). “Training”, as defined by Guskey (2000), typically includes several live sessions, in which various types of activities take place such as presentations, exploration of theory, demonstrations of skills, simulated practice, and feedback about performance. The current view of teacher PD has led to various models (e.g. training, teacher design teams, and study groups, individually guided activities, mentoring). These PD models provide teachers with a wide variety of options and opportunities to enhance their knowledge and skills.

Each country has its own policy to develop and provide teacher PD initiatives. In Slovakia, for example, there is a system for continuous education of teachers. Teachers have many opportunities to take training courses that are offered by teacher-education faculties within universities or educational institutions and accredited by the Ministry of Education of Slovak Republic (so called National accreditation system for teacher PD). After successful completion of a course, teachers receive credits that are then reflected in a special salary bonus. Additionally, schools generally allow teachers to take five days off per school year for PD. Therefore, Slovak teachers are quite motivated to participate in such PD courses (Jeskova et al., 2015a). The Slovak ICT in IBSE course was adapted to fit in the national accreditation system for teacher PD.

The case of teacher PD in Vietnam is very different. To become a teacher, candidates need to graduate from a Bachelor programme of teacher education at a university of education. With the bachelor degree, they can be employed as a full-time teacher by secondary schools. It is then mostly up to teachers to design their PD plans, which are often supported by the school. The physics teachers, for example, might participate in a training course for a few days or in a two-year full-time Master programme on physics education. The one who is enrolled in the full-time master programme can keep the job without teaching (in case the school is very far from the university) or teach a reduced load. The master programme consists of sequences of intensive courses on specified topics (i.e. two courses in parallel for one month and in the next months another two courses), followed by the Master’s research project. The first half of the programme includes physics courses. The second half is devoted to courses about PCK of teaching physics. There is no teaching practicum, but the research project of each master student must contain a classroom try-out of research ideas or educational products. The Vietnamese ICT in IBSE course was adapted to fit in the master programme as a PCK course.

2.3.3 An effective teacher-education course: characteristics and objectives

In this section, we discuss what the literature suggests to take advantage of training as traditional, common form for teacher PD and remedy its shortcomings. Based on these suggestions as well as pedagogical considerations discussed in Sections 2.1, 2.2, and 2.3, we
defined the four objectives of the course. These course objectives were the basis for a) selecting pedagogical principles underlying the course design and b) defining the course evaluation framework.

a) Advantages and shortcomings of a training course

Training as an isolated event is a common and cost-effective model of teacher education. According to Guskey (2000), training is most appropriate for sharing teaching and learning theory with many teachers and for acquisition of narrowly defined skills in a relatively short time. In a discussion about effective models of teacher PD on ICT integration, McCarney (2004) emphasised that teachers mostly valued live training sessions with hands-on activities and opportunities to consult each other and ICT-experienced instructors.

After the training event, applications of newly gained knowledge and skills to the classroom are often left for participating teachers with little or no follow-up and guidance (Barone et al., 1996). According to Fullan (1991), Lawless and Pellegrino (2007), Joyce and Showers (2002), such training has little or no effect on participants’ teaching practices. One reason for this can be teachers’ transfer problem as indicated by Joyce and Showers (1982): “one cannot simply walk from the training session into the classroom with the skill completely ready for use – it has to be changed to fit classroom conditions” (p.5). Additionally, Guskey (2000) indicated that traditional training often includes limited choices for individualisation, so it might not accommodate differences among participants with respect to their background, experience, and interest.

b) Suggestions for an effective teacher-education course

Supplementation of training with follow-up for classroom practice. The current view of effective teacher education suggests combining training with other models of teacher PD in order for individual teachers to apply new strategies and skills in the classroom and generate their new PCK. In particular, Guskey (2000) suggested:

Training sessions also must be extended, appropriately spaced, or supplemented with additional follow-up activities to provide the feedback and coaching necessary for the successful implementation of new ideas (p.23).

This is consistent with suggestions from much research on effective teacher education (e.g. J. Cradler, Freeman, R. Cradler, & McNabb, 2002; Cooper, 2003; Joyce & Showers, 2002; Roger, 2013), which highlighted the crucial combination of follow-up for classroom practice with live training. For the teacher-education course on ICT integration in particular, this combination enables to include expansion and elaboration of TPCK of ICT in IBSE teaching and to demonstrate “infusion of technology into instructional practices” (Cradler et al., 2002, p.51). According to Cooper (2003), follow-up activities often involve:

- coaching (incl. guiding, consulting, supporting) from the course instructor or peers while teachers prepare and implement the classroom try-out of what they just learned from live sessions;
- discussion after the try-out and/or in a live session in which the teachers reflect on what is learned from the try-out and receive feedback from the course instructor and/or peers.
Carefully-designed online support might make coaching more effective because it provides guidance for follow-up activities, ongoing access to support materials, and frequent communications between teachers and the course instructor outside live sessions (Voogt, 2010). The terms “training” and “workshop” are often limited to the sense of just live sessions and prescriptive procedure. Additionally, our initiative on ICT in IBSE teaching was intended for both pre- and in-service teachers. Therefore, we label it as a teacher education course.

**Teacher education as an intentional process.** According Guskey (2000), teacher education is an intentional process, which is consciously designed and implemented to bring about positive changes on teachers. To realise the intended changes, the development of a teacher education course should a) begin with clear objectives, b) ensure that such objectives are worthwhile, and c) determine with what criteria to evaluate if the objectives are attained. Teachers’ awareness and “knowledge and skill development” are often objectives of teacher education courses. In addition to these, Guskey (2000) recommended: “changes in attitudes”, “transfer of training”, and “executive control” (the appropriate and consistent use of new strategies in the classroom) as worthwhile objectives of teacher education (p.23).

c) Pedagogical considerations for our ICT in IBSE course

**Definitions of objectives of the ICT in IBSE course.** The general aim of the course was for participants to learn to integrate ICT into IBSE. The pedagogical considerations from the literature study enabled us to elaborate the general aim of the course to the four objectives of the course. The definitions of these four objectives are included in Table 2.5. Among others, the ICT in IBSE objective (3) was considered the main goal of the course. In order to reach this objective (3), participants had to achieve a certain minimum level of mastery of the ICT tools (2). The awareness objective (1) and motivation objective (4) were aimed at the course’s long-term effects on participants’ teaching practice.

**Table 2.5. Definitions of four objectives of the ICT in IBSE course.**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Awareness objective</td>
<td>Participants become aware of educational benefits of the ICT tools in science education</td>
</tr>
<tr>
<td>2. ICT mastery objective</td>
<td>Participants master skills to operate the ICT tool</td>
</tr>
<tr>
<td>3. ICT in IBSE objective</td>
<td>Participants can design, implement, and evaluate an ICT in IBSE lesson</td>
</tr>
<tr>
<td>4. Motivation objective</td>
<td>Participants are motivated to study the ICT tools further and to try out more ICT in IBSE lessons with pupils</td>
</tr>
</tbody>
</table>

**Adapted versions of the course in different countries.** We designed the ICT in IBSE course with the above objectives, then adapted, evaluated, and optimised it in different teacher-education contexts in the Netherlands, Slovakia, and Vietnam. Each version of the course had typical boundary conditions (e.g. different models of teacher education, varied timeframe), and each group of participants in each country had its own characteristics (e.g. different teaching experience, motivation; varied mastery of the ICT tools). In Chapters 4, 5, and 6, we will describe how we took these practical factors into account while adapting the course scenario and executing it in each country.
2.4 The ICT in IBSE course: design research approach and pedagogical principles

2.4.1 Design research approach and rationale

a) The ICT in IBSE course as a new educational product

The main aim of the present research was to investigate characteristics of an effective, short ICT in IBSE course for teachers and to identify successful pedagogical principles. At the start of the project, we studied the literature and found merely global, theoretical frameworks, which are somehow related (e.g. ICT, IBSE, TPCK, and teacher PD). However, there was no existing, complete model for such ICT in IBSE course to be applied. Therefore, we had to design the ICT in IBSE course as a new, educational product. To develop an effective course and to prove its effectiveness, the design process had to include several iterations of (re)designing, implementing, and evaluating the course scenario. The design research approach fits well for providing guidelines and scientific reasoning for such a design process, considering the following characteristics of design research (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006, p.5):

- **Interventionist**: design researchers cooperate with educators to intervene in the teaching and learning process in the real world, and try to refine it.
- **Iterative**: design researchers incorporate iterative cycles of (re)design, implementation, and evaluation in the design process.
- **Process-focused**: “a black box model of input–output measurement is avoided”; design researchers focus on the understanding of learning processes and the means (e.g. support materials) to stimulate these learning processes.
- **Utility oriented**: “the merit of a design is measured, in part, by its practicality for users” such as teacher educators, pre- and in-service teachers, and developers of teacher-education courses in real contexts. This increases the practical relevance of the design research for educational practice.
- **Theory-driven**: the design is based on theoretical considerations and pedagogical principles. Field testing of the design contributes to theory building, which can advance successive design efforts.

b) Relations between research and design aspects of our design research

According to Reeves (2000), design research is an approach for analysing, designing, testing, and refining solutions to complex problems in educational practice, “while at the same time constructing design principles that can inform future decisions” (p.12). This perspective applies well for our research. Considering the design aspect, we had to first model the course scenario with respect to certain objectives, using a logical theoretical framework (i.e. pedagogical principles). Next, we tested effectiveness of the course through implementing and evaluating it in a specific context (e.g. pre-service teacher education in the Netherlands). The research concerned the evaluation of the course (i.e. data collection and analysis) and provided the scientific reasoning behind the optimisation of the course for a specific context and the adaptation of the course to a different context.
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Considering the research aspect, from the literature study we defined pedagogical principles with respect to the objectives and time-constraint condition of the course. Reasoning, while implementing, evaluating, and optimising the course, would bring us new understandings of a) practical conditions for such pedagogical principles to be implemented sufficiently and b) what problems a teacher encounters in learning ICT in IBSE. Therefore, the design research could result in not only an effective design of the course but also the new knowledge and understanding of how it was developed and why it was effective. This knowledge together with the basic course design would enable the tailoring of a local version of the ICT in IBSE course in different contexts (i.e. Slovakia and Vietnam). Evaluations of the local versions of the course would enable to conclude about transferability and practical relevance of the ICT in IBSE course and generalization of pedagogical principles in different contexts.

c) Collaboration between the course designer and the course instructor

According to Shavelson, Phillips, Towne, and Feuer (2003), design research is collaborative, considering that it depends on “the knowledge and co-work of practitioners” (p.26). Adaptation, implementation, and evaluation of the ICT in IBSE course in the three countries were informed by the collaboration, as claimed by Shavelson et al. (2003), between the course instructor (the local teacher educator) and the course designer (the researcher). On the one hand, this collaboration would make the course instructors to understand the course design properly before its actual implementation. Consequently, the course implementation would become viable to the course instructors. Furthermore, the local version of the ICT in IBSE course, after having been tested and revised, was culturally adapted for each country. On the other hand, input of the course instructors through such collaboration would a) help the course designers to understand the local context at first hand and b) consolidate the understanding of the course instructors’ needs. Moreover, the course was taught in Dutch, Slovak, and Vietnamese and required different expertise of instructors regarding ICT, IBSE, and local educational context. Consequently, the collaboration with local teacher educators was indispensable.

2.4.2 Pedagogical principles underlying the short ICT in IBSE course

The requirement of having pedagogical principles for the ICT in IBSE course resulted from our selection of the design research approach for the present research. According to van den Akker (1999, p.5), pedagogical principles can be of:

- a “substantive nature”, referring to what the course should look like;
- a “procedural nature”, referring to how the course should be developed.

Pedagogical principles were the basis for designing, evaluating, and optimising the ICT in IBSE course. Considering the objectives (Table 2.5) and the general time-constraint condition of the course (see Section 1.2.2), we studied the literature and defined four pedagogical principles as summarised in Table 2.6. These principles are expected to be flexible enough to accommodate the different groups of pre- or in-service teachers in the Netherlands, Slovakia, and Vietnam. Although we defined these principles separately in the literature study, these four principles are interrelated and used together in (re)designing, implementing, and evaluating the ICT in IBSE course. In the subsections that follow, we clarify the four
pedagogical principles, their original concepts (Table 2.6), and rationale behind the selection and definition of these principles.

Table 2.6. Definition of pedagogical principles underlying the ICT in IBSE course and original concepts.

<table>
<thead>
<tr>
<th>Original concepts</th>
<th>Operational definition of pedagogical principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>One theory-practice cycle</td>
<td>Participants are required to go through at least one complete cycle of designing, implementing, and evaluating a lesson with pupils within the course.</td>
</tr>
<tr>
<td>Distributed learning</td>
<td>Participants study in live sessions and carry out individual assignments in between the sessions with support materials and in consultation with the course instructor.</td>
</tr>
<tr>
<td>Depth first</td>
<td>Participants specialise in one component of the ICT environment thoroughly rather than getting more superficial experiences with many components in limited time.</td>
</tr>
<tr>
<td>Ownership of learning</td>
<td>Participants have freedom to select what to learn and how to learn it using the course scenario to achieve the course objectives.</td>
</tr>
</tbody>
</table>

a) “One theory-practice cycle” principle

**Original concept.** A theory-practice cycle is a process in which theoretical knowledge is applied in a realistic setting. From action and reflection through this application, new understandings emerge. Completeness of one theory-practice cycle refers to the demand of theoretical reflection on meaningful, authentic feedback from application of theory in practice. According to Macdonald (1982),

Theory and practice are not only integrated through action and reflection but are a part of a larger interpretive endeavour which includes intention and direction toward the recovery of meaning and the development of understanding (p.56).

The “theory-practice cycle” concept is in line with a) the knowledge-creation metaphor for learning (Paavola et al., 2004) as discussed in Section 2.1.1 and b) the knowledge-integration framework (Gerard et al., 2011) as discussed in Section 2.2.1.

**Operational definition of the principle.** The "one theory-practice cycle" principle underlies the course, in which participants are required to go through at least one complete cycle of designing, implementing, and evaluating a lesson with pupils within the course (i.e. the ICT in IBSE lesson). The classroom try-outs of participants’ lesson plans and the evaluation of such try-outs are included as main parts of the course (see Section 2.2.1) for which sufficient time must be allocated. With this principle, the ICT in IBSE course was focused on knowledge and skill transfer through practice and follow-up.

**Rationale.** As discussed in Section 2.3.3, teachers should experience within teacher education initiatives what they need to establish in their own classrooms. Regarding teaching-method courses in particular, Lampert (2005) argued for importance of pupils’ responses for the teacher learning how to teach:

Learning about a method or learning to justify a method is not the same thing as learning to do the method with a class of students; just as learning about piano playing and musical theory is
not learning to play the piano. The later requires getting one’s hands on the instrument and feeling it ‘act back’ on one’s performance. Because teaching is situated in instructional interaction, learning how to teach requires getting into relationships with learners to enable their study of content. It is here that one learns how to teach as students ‘act back’ and responses must be tailored to their actions. (p.36)

Teacher education initiatives should be built into the teaching practice and directed at acquiring a coherent whole of knowledge, skills, and beliefs (Darling-Hammond, 1997; Hawley & Valli, 1999; Hunzicker, 2011; Rogers & Twidle, 2013). If teachers are engaged in such PD initiatives, they will be “more likely to consider professional development relevant and authentic”, and so effective teacher learning and improved teaching practice will become more likely as well (Hunzicker, 2011, p.177). Therefore, it is essential for a teacher-education initiative like our ICT in IBSE course to create the proper conditions for the teacher individually to prepare work plans with lesson materials for pupils and try them out in the classroom (Borghi, Ambrosis, & Mascheretti, 2003). Moreover, the focus of the course on the ICT in IBSE try-out might help to deal with a common complaint of teachers that they learn much theory in teacher education programmes, but do not know what to do with it in the classroom (Korthagen & Wubbels, 2001).

b) Distributed-learning principle

**Original concept.** Learning and practising strategies can be categorised as “massed” versus “distributed”, considering the temporal intensity of learning. In massed learning, the learners seek to attain as much knowledge and skills as possible within limited time and without any intermittent pauses. On the other hand, distributed learning involves a strategy of “allocating learning trials over a larger time interval, including prolonged breaks and rests” (Holzinger, Kickmeier-Rust, & Ebner, 2009, p.310).

**Operational definition of the principle.** The “distributed learning” principle underlies the course design in which participants study in live sessions (as in a traditional training) and carry out individual assignments in between the sessions with support materials and in consultation with the course instructor. Individual assignments are equally important as live sessions because these assignments enable follow-up activities with guided practice, for feedback and reflection (i.e. the ICT in IBSE try-out) at the end of the course.

**Rationale.** The distributed-learning strategy was operationalised as a principle of the ICT in IBSE course because generally, distributed learning results in better performance and in a deeper understanding than massed learning (Bloom & Shuell, 1981; Childers & Tomasello, 2002). According to Hattie and Yates (2013),

To try to learn material within a single block of time often turns out to be less effective than if the same duration of time is broken into shorter periods spaced over several days or weeks. This distributed practice effect is especially true when developing new procedural skills (p.114).

Moreover, the “distributed learning” principle logically matches with a) the focus on ICT in IBSE classroom practice and follow-up and b) the time-limited context of the ICT in IBSE course. For example, if the course were just for training manipulation skills with Coach or other software, then the most effective scenario would probably be a compact workshop in a few successive days. The ICT in IBSE course was actually aimed at the use of ICT tools to
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stimulate IBSE. This aim requires a much longer process, and so a distributed learning scenario for the course is more relevant. In particular, the distributed-learning principle enabled distributing the course with limited contact time over a longer period (e.g. 1 to 3 months) instead of forcing it in a few days. This provides a sufficient amount of time outside live sessions for participants to a) learn to use the ICT tools and b) to think, design, and try out the ICT in IBSE lesson in consultation with the school.

Working independently at a distance would be hard for participants as they may struggle with technical and pedagogical problems and suffer from regular teaching pressure, time constraints, and duties in the school and the university (see Section 2.1.3). In this case, according to Laurillard (2013), ongoing access to support materials and consultation from the course instructor would help to keep participants on task. Therefore, the support materials and consultation from the course instructor (direct and online) are mentioned as a component of the principle, which is to ensure that the distance part of the distributed scenario is effective.

c) Depth-first principle

**Original concept.** Depth-first refers to an approach, in which “a particular topic is explored in detail before moving on to the next one”, whereas breadth-first approach stimulates “a broad survey of a subject or occupational area to be established at a relatively early stage” (Avis, Fisher, and Thompson, 2010, p.136). In science education, there have been long-lasting debates about content coverage: depth versus breadth. The “breadth” view encourages teachers to cover the widest range of concepts that can be included in standardised tests. The “depth” view encourages teachers to teach fundamental concepts at a deeper level rather than covering many other concepts as well but at a more superficial level (Schwartz, Sadler, Sonnert, & Tai, 2009). For a teacher-education course on ICT integration, "depth-first" means that participants specialise in one component of the ICT environment thoroughly rather than getting more superficial experiences with all components in limited time. The participants are expected to study the other components in depth on their own after the course.

**Operational definition of the principle.** For the ICT in IBSE course, the "depth-first" principle means that individual participants specialise in only one ICT tool (by choice) after having been introduced to the possibilities of the three tools: data logging, video measurement, and modelling (Stage 1). The one-tool specialisation includes the following stages:

- **Stage 2.** Mastering skills to operate the chosen tool,
- **Stage 3.** Designing the ICT in IBSE lesson that makes use of the chosen tool,
- **Stage 4.** Teaching the ICT in IBSE lesson with the chosen tool,
- **Stage 5.** Evaluating the ICT in IBSE try-out with the chosen tool.

We expected that the participants would be inspired and able to transfer their successful experience of learning one tool in depth (depth first) to learning other tools after the course (breadth later). If more time can be scheduled for participants to develop ICT skills, then the one-tool specialisation can start from Stage 3.

**Rationale.** Schwartz et al. (2009) carried out an empirical study to relate the performance of 8310 college students in introductory science courses in 55 colleges/universities in the United States to the amount of content covered in their high school
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science courses. The main conclusion was that “a robust positive association exists between high school science teaching that provides depth in at least one topic and better performance in introductory postsecondary science courses” (p.26). Pupils, who reported breadth in their high school course (i.e. covering all major topics), did not appear to have any advantage in the introductory science courses. This outcome was in line with many other research outcomes (e.g. Beittel et al., 1961; Eylon & Linn, 1988), confirming that content should value depth over breadth of coverage.

Moreover, according to NGSS Lead States (2013),

In an information age – an important role of science education is not to teach “all the facts” but rather to prepare students with sufficient core knowledge so that they can later acquire additional information on their own. An education focused on a limited set of ideas and practices in science and engineering should enable students to evaluate and select reliable sources of scientific information and allow them to continue their development well beyond their K–12 school years as science learners, users of scientific knowledge, and perhaps also as producers of such knowledge (p. xv).

As adult learners, course participants should focus on core concepts and skills within an extensive domain, and they can be also expected to continue studying other concepts and skills further on their own.

In particular for the ICT in IBSE course, the time constraints did not allow participants to go deeply into all three ICT tools. Even for one tool, it is impossible to learn and memorise every detail in live sessions. Furthermore, a certain level of depth regarding ICT knowledge and skills would be critically required for the participants in order to design and teach a lesson with the ICT tool (i.e. course objectives). Therefore, the participants indeed had to specialise in only one ICT tool and pursue in-depth learning of this tool first.

The tool in which individual participants specialise should suit their background, experience, needs, and interest. It also needs to match with their teaching conditions (e.g. availability of the tool and equipment in the school, pupils’ experience of using the tool, priorities of school colleagues). This is why we highlight “by choice” in the definition of the depth-first principle. Additionally, we also highlight that the participants would be introduced to the possibilities of the three ICT tools before specialising in only one tool. This is because of two reasons. First, awareness of all three ICT tools (possibilities and relevance) would enable individual participants to choose a suitable, priority tool that they really desire or need to learn. Second, this awareness would contribute to motivation of the participants to learn further on their own beyond the course.

When applying depth-first, we had to make the breadth-later vision clear to the participants and ourselves. For the ICT in IBSE course, this breadth-later vision is quite promising, considering that the way to specialise in a particular tool (e.g. data logging) is not much different from that for other tools (e.g. video measurement and modelling). This consideration is more valid as all the ICT tools are integrated in the same Coach software environment (see Chapter 3, Section 3.1.1). With support materials (see Section 3.1.4) and via direct and online support, we would help the course participants to fulfil the four stages of the one-tool specialisation mostly on their own. The participants could feel not knowing everything about the tool yet, but they would appreciate the educational benefits of the tool
and believe in their ability. They would know how and desire to learn further about the ICT tools, including the ones in which they did not specialise during the course.

d) "Ownership of learning" principle

Original concept. From a constructivist perspective, ownership of learning refers to the autonomous, responsible, and active role that individual learners play in construction of their understandings (Rainer & Matthews, 2002). Learners’ ownership is mainly defined by their actual choices regarding tasks (e.g. level of difficulty, type of task), their control of such tasks (e.g. how the task is determined, carried out, and reported), and their motivation towards the task objectives (Enghag & Niedderer, 2007). Just offering freedom of learning is not enough for learners to take their ownership. Rather, ownership of learning needs to be “encouraged and nurtured” in proper conditions and through suitable processes (Dudley-Marling & Searle, 1995, as cited in Rainer & Matthews, 2002, p.28).

Operational definition of the principle. “Ownership of learning” was chosen as one of the four pedagogical principles of the ICT in IBSE course. It is operationalized by giving participants the freedom to select what to learn and how to learn it using the course scenario and support materials in order to achieve the course objectives. The individual participants were stimulated and supported to pursue their self-tailored learning process in which they made their own choices regarding:

• which tool to specialise in, which support materials to use;
• how much time to spend outside live sessions, how to carry out the assignments;
• which topic the ICT in IBSE lesson would be about, which inquiry components (Table 2.3) to focus on in the ICT in IBSE try-outs.

Rationale. According to Hunzicker (2011), teachers as adult learners tend to be intrinsically motivated by open-ended opportunities to address problems and create solutions that relate directly to their practical teaching. They often use their teaching experiences to make sense of new knowledge. Consequently, teacher education initiatives should involve and support individual teachers in identifying what they need to learn, devising plans to meet these goals, and pursuing their self-tailored learning process (Hawley & Valli, 1999).

The ICT in IBSE course is aimed at the classroom try-out, whereas teaching conditions are different among schools. Individual participants know best about their own teaching situations, and so with the freedom of choice, they can choose a topic or activity which they are most interested in and which fits the conditions at their school. The “ownership of learning” principle assumes that the participants take an autonomous, responsible, and active role in learning when they a) appreciate what to learn (i.e. course objectives), b) know how they learn it best, and c) receive appropriate support as needed. Consequently, it was crucial for the participants to quickly become aware of their freedom of choices with respect to the course objectives and become aware of available support from the course instructor (i.e. course scenario) and of variety of support materials (see Section 3.1.4). Therefore, “using the course scenario and support materials” is mentioned as a component of the principle, which helps to support the participants’ ownership of learning.
2.5 Summative conclusions and considerations from the literature study

In the explorative phase of this design research (see Chapter 1, Figure 1.1), we defined research problems (Chapter 1), studied the literature (Chapter 2), and took the following pedagogical considerations for next phases of the design and research process:

- Data logging with sensors, video measurement, and modelling are suitable tools to stimulate inquiry. Integration of this technology with IBSE was the key theme and objective of the course (see Sections 2.1.1 and 2.1.2).
- To be realistic and worthwhile, integration of ICT in IBSE needed to focus on a limited number of inquiry skills (Table 2.3), especially those that stimulate back and forth thinking between the physical and theoretical worlds. The participants had to operationalise such inquiry skills in the lesson plan for pupils to exercise and scaffold such exercises explicitly in the classroom (see Sections 2.1.3, 2.2.2).
- From both TPCK and teacher PD perspectives, the classroom try-out of ICT in IBSE lesson is crucial. Consequently, we had to prepare proper conditions during the course to stimulate, guide, and support the participants (e.g. Forms 2 and 3, consultation from the course instructor) to implement the try-out faithfully and make the most of it (see Sections 2.2.1, 2.2.2, and 2.3.3).
- The ICT in IBSE course was aimed at the four objectives (Table 2.5) and based on the four pedagogical principles (Table 2.6). Operationalization of these principles in the course scenario with respect to the course objectives had to take into account characteristics of participants and boundary conditions of the course in the local context. These characteristics and conditions were very different among the three contexts (see Sections 2.3.1 and 2.3.2).
Chapter 3 Course design and research design

Chapter 3 presents design decisions and methodological frameworks for actual implementation, optimisation, and evaluation of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam, which will be presented in Chapters 4, 5, and 6 respectively. In particular, Section 3.1 contains practical explorations, which resulted in the selection of the Coach platform for data logging with sensors, video measurement, and dynamical modelling and the selection and development of support materials for the course. Section 3.2 clarifies the initial scenario of the ICT in IBSE course in the Dutch context; this scenario reflects explicit operationalization of the four pedagogical principles with respect to the four course objectives. The instruments used for data collection and analysis are described in Section 3.3. Sections 3.4 presents the general design of the Dutch, Slovak, and Vietnamese case studies for evaluating and optimising the ICT in IBSE course. Considering the Dutch case study as the main research and development of the ICT in IBSE course, we focussed on clarifying the evaluation framework for the Dutch case study in this section; this framework summarises which and how instruments were used and combined to address each evaluation question. Section 3.5 concludes the main design decisions and methodological frameworks, which will be used, but not repeated in Chapters 4, 5, and 6.

3.1 Practical explorations and support materials for the ICT in IBSE course

When further operationalising pedagogical principles in the course design, we had to explore contextual possibilities and consider practical factors. Additionally, we had to develop/select, try out, and refine a) instruments for data collection and analysis and b) support materials before they were formally used in the first cycle of the course. These required practical explorations in the explorative phase of this design research. In subsections that follow, we summarise these practical explorations as well as decisions and implications for the ICT in IBSE course.

3.1.1 Exploration of the Coach platform for the course

a) Coach and support materials for mastering the Coach tools

There are several available hardware and software environments for data logging with sensors, video measurement, or dynamical modelling in science education. We used the Coach platform, which integrates all three ICT tools in a single computer environment (incl. the Coach software, sensors, and interfaces; Figure 3.1) and which includes flexible, extensive authoring possibilities (Figure 3.2). Coach has been conceptualised and developed since 1986 and optimised to the Coach 6 and recently Coach 7 version. Coach was developed by CMA in the Netherlands. From the start, it was already aimed at international use. Coach is now available in about 20 countries (e.g. Slovakia, Italy, and Mexico) and in different languages (e.g. Dutch, English, and Slovak). Our choice of Coach was influenced by the fact that Coach is dominant in Dutch schools and even integrated in textbooks and the examination programme. This availability of Coach in the school is a favourable condition for the ICT in IBSE try-out.
Along with almost 30 years of development of Coach, Coach activities have been developed as support materials for teachers’ use in teaching (ready-to-use experimentation/modelling activities) and for learning Coach skills (tutorial activities with prescriptive instructions). Additionally, CMA has published introductory slides, which introduce characteristics and possibilities of the ICT tools. Through in-service trainings for Dutch teachers and EC-funded projects (e.g. ICT for IST, KLiC, and ESTABLISH), these Coach support materials were used, evaluated, and optimised. We selected the Coach activities and slides as support materials for the ICT in IBSE course (Table 3.1).

![ICT tools](http://www.cma-science.nl/)

**Figure 3.1.** ICT tools for data logging with sensors, video measurement (i.e. data video), and dynamical modelling are integrated in a single Coach hardware and software environment (http://www.cma-science.nl/).

**b) Suitability of Coach for the ICT in IBSE course**

Coach has been chosen from the outset, and it matches with the objectives and pedagogical principles of the course. First, the three Coach tools share the same software interface with many common features (e.g. data processing and analysis, authoring possibilities). Therefore, it is very likely that after mastering one tool (e.g. data logging), learning other tools (e.g. video measurement) will be relatively easy and go faster. This makes Coach suitable for the depth-first principle. Second, the “ownership of learning” principle enables participants’ freedom to decide what to do with the ICT tool with respect to the ICT in IBSE classroom try-out. The more options and possibilities the chosen computer platform can provide, the more practical this principle becomes. The Coach platform has sufficient features for data logging, video measurement, and modelling as described in Chapter 2, Section 2.1.2 and extra advanced features, which can be found in Heck, Kedzierska, and Ellermeijer (2009) and on the CMA website. Furthermore, Coach enables teachers and pupils to modify existing experimentation/modelling activities and develop such activities from scratch. Coach also allows teachers to add multimedia (e.g. text, photo, video, hyperlinks) to the Coach activity (Figure 3.2), which can be used as interactive demonstrations and/or for pupils’ individual/group assignments. To conclude, what can be
developed in Coach is not only in the hand of the designer but also teachers and pupils. This enables the participants to realise their own ideas for the ICT in IBSE activity, to adjust this activity to their teaching conditions (incl. equipment, pupils, and curricula), and so to appreciate their ownership of learning (Donnelly et al., 2014).

Figure 3.2. Screenshot of a Coach activity with data-video pane, graph, text, and image; the activity is developed for pupils to investigate motion characteristics of tumbler-like pendulums.

Additionally, “distributed learning” and “one theory-practice cycle” principles are more likely if the ICT tools are available in the school, and pupils are able to learn to handle such ICT tools in their inquiry activities. Coach matches with these demands, too. Ellermeijer, Heck, and colleagues showed actual effects of Coach in stimulating inquiry practices of pupils within ICT-enhanced experimentation/modelling activities. Pupils are able to learn and handle Coach in regular laboratory lessons and for their research projects (e.g. Heck & Uylings, 2005; Heck, 2007, 2009; Heck, Ellermeijer, & Kedzierska, 2009; van Eijck, Goedhart, & Ellermeijer, 2005).

3.1.2 Exploration of possibilities for the course and its practical conditions in different countries

In the cyclic research phase, we had to implement, evaluate, and optimise the ICT in IBSE course for Dutch student teachers. This research phase was also aimed to test generalizability of the pedagogical principles and transferability of the ICT in IBSE course (incl. support materials) in different countries and different contexts of pre- and in-service teacher education. Therefore, we had to explore testing opportunities in universities and educational institutes in various countries where we had contact.
We introduced the ICT in IBSE course in ESTABLISH project meetings\(^1\); two teacher-education groups from Slovakia and Italy showed interest and proposed to cooperate. The Slovak colleagues regularly offered in-service trainings for large groups of science teachers (Jesková et al., 2015a). Moreover, they were involved in development of the Coach activities and introductory slides, which were used as support materials in the ICT in IBSE course. Eventually, they decided to offer in-service courses on ICT in IBSE (see Chapter 5). Unfortunately, the opportunity to test the course in Italy then evaporated when the government decided that for several years, there would be no new admissions to the teacher-education programme.

We contacted the physics-education department of Hanoi National University of Education (HNUE) and asked for cooperation in adaption and implementation of the ICT in IBSE course. The incentive for exploring possibilities for the course in Vietnam was because we understand the Vietnamese context well, and this context is very much different from the Dutch and Slovak one. For example, there was/is almost nothing related to ICT tools for data logging with sensors, video measurement, and dynamical modelling either in the curriculum or in the schools. If the pedagogical principles still hold up and the course remains effective in Vietnam, then generalizability of the pedagogical principles and transferability of the course design would be strongly supported. In order to prepare for the Vietnamese course, we borrowed Coach hardware from CMA and asked CMA’s permission to install Coach software on the university and school computers (see Chapter 6). The department decided to offer the ICT in IBSE course as part of the Master programme on Physics Education.

In order to explore characteristics of the participants and boundary conditions of the ICT in IBSE course before the first cycle in each country, we collected background data from participants through the pre-course questionnaire and interviewed the local course instructor. Collection and analysis of data from other sources (e.g. classroom observations, communication records) during the course implementation generated additional descriptive data about the characteristics of the participants and the boundary conditions of the course.

3.1.3 Exploration studies: aims, results, and implications for the course

In this section, we describe the two exploration studies carried out in the exploration phase of the present design research: a study of an ICT workshop and the other on pupils’ learning of Coach skills.

a) Study of an ICT workshop

Context, aims, and methods. A two-day ICT workshop was offered in September 2012 for 16 teacher educators, who were involved in the ESTABLISH project. The participants were familiar with ICT, especially measurement with sensors, but most of them did not have any experience with Coach. Through the introductory slides and Coach demonstrations, the workshop instructors first introduced Coach data logging, video measurement, and modelling to the participants. Next, the participants practiced the Coach tutorial activities to learn Coach skills. Finally, they explored the Coach exemplary activities.

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\(^1\) For more information about the ESTABLISH EC-funded project, see its website: [http://www-establish-fp7.eu/](http://www-establish-fp7.eu/)
and discussed how to integrate these Coach tools in the IBSE activities, which were already developed within the ESTABLISH project. Within this workshop, we studied to what extent the participants mastered the Coach tools and whether the Coach support materials were useful for the Coach training. Data collection was based on a) pre- and post-questionnaires, b) observations of the hands-on sessions, c) interview of participants, and d) analysis of Coach result files, which resulted from practice of participants with the Coach activities.

**Results and implications for the ICT in IBSE course.** After the workshop, 12 out of 16 participants achieved sufficient skills with Coach; 7 participants developed their own new Coach activities. The wide range of Coach activities and related flexible scenario actually a) accommodated participants with different experiences and interests and b) enabled their effective learning of Coach in small groups. As teacher educators, the participants evaluated the Coach activities as very useful support materials for Coach beginner users to learn Coach skills. The participants were able to transfer their experience with other ICT platforms in learning Coach quickly.

**b) Study on pupils’ learning of Coach skills**

**Context, aims, and methods.** We cooperated with a Dutch physics teacher to design a series of four, hands-on, 50-minute lessons. The lesson series was aimed at 17 pupils of a fourth pre-university class (aged 16) to acquire skills with Coach video measurement; these pupils did not have experience with video measurement and with Coach. They would learn Coach skills by practicing Coach tutorial activities in the classroom and consulting the teacher as needed. The Coach activities for the first two lessons were very prescriptive and thorough. Those for the last two lessons were more investigative and required pupils to recall manipulation skills, which they practised in previous lessons. With this try-out, we studied if pupils were able to master Coach skills mostly on their own, using the Coach support materials and related carefully-structured scenario. The hands-on sessions were recorded on video, and during these sessions notes on pupils’ problems were taken. Moreover, we developed and provided pupils with a performance, individual, computer test at the end of the final lesson. Without any technical instructions, pupils were required to verify the law of mechanical energy conservation by analysing a given video of a pendulum.

**Results and implications for the ICT in IBSE course.** The pupils did not meet serious problems in following prescriptive instructions in practicing video measurement. In the last two lessons, they got stuck sometimes in carrying out the Coach activities that provided less complete instructions and involved conceptual understanding of the phenomena. After quick help of the teacher, the pupils could get over the hurdles and eventually complete these activities. About the learning outcome, 12 out of 17 pupils could pass the performance test. They showed their sufficient skills by fluently scaling the video, collecting data, calculating secondary quantities, and plotting graphs of different variables. The Dutch teacher informed us that he has used this lesson series and the Coach tutorial activities for his classes in the past three years with positive pupil result. This positive result of the pupils reinforced the approach for training Coach skills. This approach consisted of three components: Coach support materials, a clear scenario, and direct help of Coach experts in live sessions. We would apply this approach for the initial scenario of the ICT in IBSE course.
3.1.4 Support materials for the ICT in IBSE course

Table 3.1 shows support materials, which were selected and developed for live activities and individual assignments of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam. In this section, we describe these support materials\(^2\). The support materials that were used in the Slovak and Vietnamese courses were translated to the local language. The English version of the support materials can be downloaded from the course website\(^3\). In Section 3.2, we will clarify when each type of support materials was used in the initial scenario with respect to the course objectives (Table 3.2). We summarise this in Table 3.4; the labels about the support materials (e.g. S, C2, F3) are used as reference in the table.

*Table 3.1. Support materials used for different versions of the ICT in IBSE course in different countries (i.e. the Netherlands, Slovakia, and Vietnam).*

<table>
<thead>
<tr>
<th>Label</th>
<th>Support materials*</th>
<th>Dutch course</th>
<th>Slovak course</th>
<th>Vietnamese course</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Introductory slides for the ICT tools and possibilities of using these tools in science education</td>
<td>✔ ✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>Coach activities as introductory materials to illustrate the Coach software and hardware environment (called Coach introductory materials)</td>
<td>✔ ✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>Coach activities as tutorial materials to practice manipulation skills with the ICT tool (called Coach tutorial materials)</td>
<td>✔ ✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Coach activities as exemplary materials about how to integrate the Coach tool in inquiry-based science lessons (called Coach exemplary materials)</td>
<td>✔ ✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td><em>Form 1 for the assignment report</em> on practice with the ICT tool</td>
<td>✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2</td>
<td><em>Form 2 for the lesson plan</em> of the ICT in IBSE lesson</td>
<td>✔ ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td><em>Form 3 for participants’ self-evaluation</em> of the ICT in IBSE try-out</td>
<td>✔ ✔</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) The checkmark “✔” indicates which support materials were used for the local version of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam.

a) Introductory slides

The introductory slides were to introduce concepts, characteristics of the ICT tools, and possibilities of using these tools in school science (Figure 3.3). These characteristics and possibilities are described in Chapter 2, Section 2.1.2.

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\(^2\) These materials are described in Tran, Van den Berg, Ellermeijer, and Beishuizen (2014).

\(^3\) The course website: [http://www.cma-science.nl/ICTcourse/index.html](http://www.cma-science.nl/ICTcourse/index.html); user name: ICT and password: cmaitc2015 are required to access the website.
b) Coach activities as introductory, tutorial, and exemplary materials

From the Coach library, 10 activities were selected as introductory materials to illustrate the software and hardware environment (i.e. simple manipulations, elementary concepts). Carrying out these activities does not require any previous experience with the Coach platform. The tutorial materials include 17 activities with step-by-step written instructions (Figure 3.4a) and video clips (Figure 3.4b). Following these instructions to practice the tutorial activities, the participants would be able to master basic skills and concepts corresponding to a particular tool.

The exemplary materials include 52 complete experimentation/modelling activities within the Coach platform, which are focussed on a particular topic (e.g. Boyle’s law) and a few inquiry components (Figure 3.5). These exemplary materials were primarily designed for pupils to work with Coach on their own with written instructions and carry out experiments or implement dynamical models. In order for pupils to be able to handle the activity independently, the embedded written instruction includes many details that make such instruction rather prescriptive. However, it also includes some questions after the execution of experiment/model to stimulate minds-on thinking and a few inquiry opportunities (Figure 3.5). If the teacher manipulates the Coach activity instead of pupils, then it becomes a means for interactive demonstrations. These exemplary activities are suitable examples of how to
start teaching with the Coach tool; they can be used by the course participants as ready-to-use ICT in IBSE activities. The Coach authoring facility enables to modify the written instruction embedded in the Coach exemplary activity. The course participants could make the exemplary activity more investigative while still keeping it reasonable for pupils regarding ICT manipulations. Therefore, the participants could also use the Coach exemplary materials for further development, considering more and/or different inquiry opportunities to be included.

Figure 3.5. Screenshot of an exemplary activity with prescriptive instructions.

We practiced all of the selected Coach activities and checked unclear and insufficient points in the text and video instructions. Next, we tried out these Coach activities in the ESTABLISH workshop for teacher educators. After that, we categorised the Coach activities into three packages: data logging, video measurement, and modelling. Each package included three categories of the Coach activities: introductory, tutorial, and exemplary. This would help the participants to easily access Coach support materials that they needed.

c) Forms for individual assignments

Based on explicit requirements of individual assignments, we developed three forms that were to a) provide structure for assignment reports, b) stimulate participants to pay attention to crucial demands of the assignments, and c) allow us to collect sufficient data from participants’ assignment reports. Development of Forms 2 and 3 was based on the framework for developing, executing, and evaluating the ICT in IBSE lesson as presented in Chapter 2, Section 2.2.2. In the following paragraphs, we summarise these three forms of which the entire versions can be found in Appendix B.

**Form 1 for the assignment report on practice with the ICT tool.** The participants had to take notes during their practice with the Coach tutorial materials, then reflect and report on the following evaluation points:

- What were new Coach-related knowledge and skills that they learnt after practicing each Coach tutorial material? What problems did they meet?
- What would they like to learn more about the Coach tool?
• What did they see as possibilities and challenges in using the Coach tool in an inquiry way?

**Form 2 for the ICT in IBSE lesson plan.** The list of 22 categories of inquiry practices within the ICT in IBSE activity (see Chapter 2, Table 2.3) was given at the end of Form 2. At the “objective” section of Form 2, the participants had to indicate which inquiry categories in the given list they aimed at for their ICT in IBSE lesson (Stage 1, Figure 2.9 in Chapter 2). After the “objective” section, they had to describe the intended teaching and learning scenario, which includes four phases: 1) orientation, 2) design of experiment/model, 3) execution, 4) interpretation, and 5) What did we learn. Additionally, the participants had to fill out other boxes in Form 2 regarding requirements as follows:

- What will you do to make sure the lesson is minds-on?
- Prepare examples of teacher questions which can be used when going around to stimulate minds-on.

Through these intended activities and prepared questions, the participants had to specify *opportunities for pupils within the experimentation/modelling activity to exercise inquiry components* (Stage 2, Figure 2.9 in Chapter 2). Form 2 would focus participants’ attention on concrete components of inquiry practices and make them aware of the needs to stimulate and guide pupils in such inquiry practices.

**Form 3 for self-evaluation of the ICT in IBSE try-out.** The framework for evaluating the ICT in IBSE lesson (see Chapter 2, Figure 2.9) was elaborated in Form 3 for the participants to self-evaluate their ICT in IBSE try-out. The participants had to reflect on their try-outs and justify the following evaluation points:

- Which inquiry skills were observed in the lesson? What evidence?
- Through each phase of the lesson, what did not go as intended and why?
- If you teach the ICT-IBSE lesson at the next time, what will you change?

### 3.2 Initial scenario of the ICT in IBSE course

In order to elaborate and present the course scenario, we had to allocate the ICT in IBSE course in a specific context with certain boundary conditions. Considering that the main development of the ICT in IBSE course was in the Netherlands, we describe the initial scenario of the Dutch ICT in IBSE course in this chapter. The Dutch course was limited to 28 hours of total study time, equivalent to 1 ECTS. In Cycle 1, it was spread over five weeks. Details about the Dutch context can be found in Chapter 4. Chapter 4 will focus on implementation and optimisation of this initial scenario in Cycle 1 towards a more optimal one in Cycle 3. In this section, we first present an overview of the initial scenario of the ICT in IBSE course (Dutch context). Next, we describe the programme for three live sessions, requirements for two individual assignments, and the online support for course participants.

#### 3.2.1 Overview of the initial course scenario

*a) Components of the course scenario*

The course scenario included a programme of particular activities in *live sessions* (incl. content, format, and timing) and explicit requirements for *individual assignments* with
online support. The support materials were used in live sessions and for individual assignments of the course (Table 3.1). The online support included:

- **an online platform** (e.g. Moodle, website) where the participant could review the course description (i.e. programme, assignments) and browse the support materials for the individual assignments;
- **online consultation from the course instructor** (via forum and/or email) by which the participant could deal with their technical and pedagogical problems while carrying out the assignments. The course instructor checked the forum and/or email on a daily basis in order to react to the participants’ questions early.

Operationalization, implementation, and optimisation of the course scenario were aimed at the four objectives of the course:

1. **Awareness objective**: Participants become aware of educational benefits of the ICT tools in science education.
2. **ICT mastery objective**: Participants master skills to operate the ICT tool.
3. **ICT in IBSE objective**: Participants can design, implement, and evaluate an ICT in IBSE lesson.
4. **Motivation objective**: Participants are motivated to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.

b) Operationalization of the four pedagogical principles in the initial scenario of the ICT in IBSE course with respect to the four course objectives

Considering the objectives, time-constraint conditions, pedagogical considerations, and practical implications for the ICT in IBSE course, we operationalised the pedagogical principles further in the initial scenario of the course as visualised in Figure 3.6 and summarised in Table 3.3.

---

**Figure 3.6. Overview of the initial scenario of the ICT in IBSE course (i.e. scenario of the Dutch course in Cycle 1).**

Figure 3.6 shows a) four main activities corresponding to the sequences of three live sessions and two individual assignments and b) what types of support materials (Table 3.1)
and instruments (Table 3.5) would be used and when. These support materials, assessment instruments, and their abbreviations are described in Sections 3.1 and 3.3. The upside-down triangle reflects the depth-first principle of the course: the participants start from a broad perspective about possibilities of all three ICT tools (broad on surface), and then individually specialise in only one ICT tool by choice to design, teach, and evaluate one lesson to one class, aiming at just a few components of inquiry practices (going narrow and deep to the core of ICT in IBSE teaching). Table 3.2 indicates to which course objective(s) each pedagogical principle and each type of the support materials contributed dominantly.

Table 3.2. Matrix of the course objectives, pedagogical principles, and support materials, showing to which course objective(s) each principle and each type of the support materials contributed dominantly.

| Operationalization of the pedagogical principles in the course scenario | Course objectives* |
|---|---|---|
| | Awareness | ICT in mastery | ICT in IBSE | Motivation |
| **One theory-practice cycle**: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson in the classroom within the course. | ✓ | ✓ | ✓ | |
| **Distributed learning**: participants study in live sessions and carry out individual assignments in between the sessions with support materials and in consultation with the course instructor. | | | ✓ | |
| **Depth first**: participants master specialise in only one ICT tool by choice after having been introduced to the possibilities of the three ICT tools (i.e. data logging, video measurement, and modelling). | ✓ | ✓ | ✓ | |
| **Ownership of learning**: participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives. | ✓ | ✓ | |

<table>
<thead>
<tr>
<th>Support materials</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S: Introductory slides</td>
<td>✓</td>
</tr>
<tr>
<td>C1: Coach introductory materials</td>
<td>✓</td>
</tr>
<tr>
<td>C2: Coach tutorial materials</td>
<td></td>
</tr>
<tr>
<td>C3: Coach exemplary materials</td>
<td>✓</td>
</tr>
<tr>
<td>F1: Form 1 for the assignment report on practice with the ICT tool</td>
<td></td>
</tr>
<tr>
<td>F2: Form 2 for the lesson plan of the ICT in IBSE lesson</td>
<td></td>
</tr>
<tr>
<td>F3: Form 3 for participants’ self-evaluation</td>
<td></td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates to which objective(s) of the course each pedagogical principle and each type of support materials contributed dominantly.

The Dutch ICT in IBSE course was taught by Dutch science-teacher educators (one of whom was the PhD supervisor) and Coach experts (one of whom was the other PhD supervisor) as course instructors. The researcher was involved in coordination of the course in Cycles 1, 2, and 3 of the Dutch course. In Cycle 4, the coordination activities were shifted to the course instructors.

### 3.2.2 Programme of live sessions and requirements for individual assignments

The initial scenario included three live sessions, two individual assignments, and the pre-course preparation activities. Assignment 1 was intended for the two weeks in between Sessions 1 and 2, and Assignment 2 was intended for the three weeks in between Sessions 2
and 3 (Table 3.3). Within the 28 hours of total study time, 9 hours were allocated to the three live sessions (i.e. 3 hours each), and 19 hours were anticipated for the two assignments and the pre-course preparation. In each cycle, there were three instructors in charge of different activities of the course.

The instructors of the Dutch ICT in IBSE course were Dutch science-teacher educators and Coach experts. The Coach experts regularly provide ICT training for teachers. These instructors of the Dutch course were involved in development of support materials that were used in the course.

Table 3.3. Summary of intended activities in live sessions and requirements for individual assignments in the initial scenario of the ICT in IBSE course (i.e. scenario of the Dutch course in Cycle 1).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time frame*</th>
<th>Participants’ activities</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-course preparation**</td>
<td>1 week</td>
<td>• Reading the course description.</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Installing the Coach software.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reading the introductory slides.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practising the Coach introductory activities.</td>
<td></td>
</tr>
<tr>
<td>Session 1</td>
<td>3 hours</td>
<td>• Listening to the introduction and demonstration of the three ICT tools.</td>
<td>Plenary</td>
</tr>
<tr>
<td>Assignment 1**</td>
<td>2 weeks</td>
<td>• Choosing one of the three ICT tools and practising manipulation skills through the Coach tutorial activities.</td>
<td>Group of two or individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Receiving Assignment 1.</td>
<td>Plenary</td>
</tr>
<tr>
<td>Assignment 2**</td>
<td>3 weeks</td>
<td>• Continuously practising the chosen ICT tool to acquire the basic manipulation skills.</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Writing Assignment-1 report.</td>
<td></td>
</tr>
<tr>
<td>Session 2</td>
<td>3 hours</td>
<td>• Discussing manipulation problems related to Assignment 1.</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Listening to the instruction about IBSE.</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Receiving Assignment 2.</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Choosing the topic, preparing the Coach activity for the ICT in IBSE lesson.</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Finalising the ICT in IBSE lesson plan.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Trying out the ICT in IBSE lesson with pupils.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Self-evaluating the ICT in IBSE try-outs (i.e. main part of Assignment-2 report).</td>
<td></td>
</tr>
<tr>
<td>Session 3</td>
<td>3 hours</td>
<td>• Reporting and evaluating the try-outs.</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discussing added value of the ICT tools.</td>
<td>Plenary</td>
</tr>
</tbody>
</table>

(*) Total study time (i.e. 28 hours) was divided into 9 contact hours and 19 hours outside live sessions. The course was spread over 5 weeks (Cycle 1 of the Dutch ICT in IBSE course).

(**) While preparing for the course and carrying out individual assignments, the participants were encouraged to use the support materials and the online support.

**Session 1**

During Session 1, the participants were introduced to the three ICT tools and possibilities of using these tools in school science, especially in IBSE through the introductory slides. In this plenary presentation, the course instructor demonstrated three or four specific possibilities, using the Coach exemplary activities. Next, the individual participants were expected to specialise in only one tool by choice. They practiced manipulation skills with their chosen tool in a group of two or individually (Figure 3.7a),
following the text instructions embedded in the *Coach tutorial activities*. Assignment 1 was assigned at the end of the session.

**Assignment 1**

Assignment 1 required the individual participants to continue practising their chosen ICT tool to acquire manipulation skills, using the Coach *tutorial and exemplary activities*. The participants were encouraged to consult the course instructor via the online forum of the course (Figure 3.8) whenever they encountered difficulties with the Coach tool. Using *Form 1* (Appendix B), they had to write the Assignment-1 report about what they learnt, what they struggled with, and what they wanted to learn more in regard to their chosen tool. The Assignment-1 report had to be submitted before Session 2.

**Session 2**

During Session 2, the participants discussed in plenary about manipulation problems related to Assignment 1, using the Assignment-1 report. After that, the instructor gave a plenary instruction to IBSE (Figure 3.7b). Next, individual participants received Assignment 2, chose the topic for the ICT in IBSE lesson, and started to prepare the Coach activity utilising the chosen Coach tool. The Coach activity is an integral component of the ICT in IBSE lesson plan; the other component is a learning scenario in the classroom, using the Coach activity. The participants had options of using one of the Coach exemplary activities or modifying it to be more suitable for an inquiry-based lesson and to match with their teaching conditions. However, the participants were also encouraged to develop a new Coach activity that would fit their chosen topic for the ICT in IBSE lesson.

*Figure 3.7.* Photographs of participants’ activities in chronological order during the course scenario: a) practising manipulation skills with Coach, b) listening to the IBSE instruction, c) trying out the ICT in IBSE lesson with pupils, d) reporting back in the course. These photographs were taken in Cycle 1 of the Dutch ICT in IBSE course.
Assignment 2

Assignment 2 required the individual participants to finalise the ICT in IBSE lesson plan, using Form 2 (Appendix B). Before Session 3, the participants had to try out their lesson plans with pupils. The participants were expected to consult the school mentor and the course instructor about the lesson plan before its classroom try-out. Using Form 3 (Appendix B), they had to self-evaluate their ICT in IBSE try-out. The Assignment-2 report (incl. the lesson plan and the self-evaluation of the try-out) had to be submitted before Session 3.

Session 3

During Session 3 the participants in plenary brought back what they had done and reflected on what they had experienced with the try-outs (Figure 3.7d), using the Assignment-2 report. After that, the participants took turns to comment on added value of the ICT tools in science education.

In Table 3.4, we summarise when each type of support materials was used in the initial scenario with respect to the course objectives.

Table 3.4. Matrix showing when each type of support materials was used in the initial course scenario.

<table>
<thead>
<tr>
<th>Support materials*</th>
<th>Preparation</th>
<th>Session 1</th>
<th>Assignment 1</th>
<th>Session 2</th>
<th>Assignment 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>S: Introductory slides for possibilities of the ICT tools</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>C1: Coach introductory activities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>C2: Coach tutorial activities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>C3: Coach exemplary activities</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>F1: Form 1 for the assignment report on practice with the ICT tool</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>F2: Form 2 for the lesson plan of the ICT in IBSE lesson</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>F3: Form 3 for self-evaluation of the ICT in IBSE try-out</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates to when each type of support materials was used in the initial scenario of the course.

3.2.3 Online support and coordination of the course

The online support was to provide the participants with ongoing access to the support materials and the consultation from the course instructor. The online platform with support materials and the consultation forum for the participants were designed and implemented within the ESTABLISH project’s Moodle environment (Figure 3.8). The participants were encouraged to consult each other and the course instructor about their problems via the online forum while working on the assignments. They had to write and submit assignment reports before the intended time (see Section 3.2.2), especially submitting the lesson plan before its try-out. The Slovak version of the Moodle platform was translated and used for the Slovak ICT in IBSE course.

To keep the participants on task, we would send reminder emails to the participants three days before each deadline. We would phone ones who did not submit anything after the deadline and did not contact us about their assignment progress. The phone call was to remind these participants about the assignment and offer direct help if necessary. Via the course
description and in Session 1, we suggested the priority for participants to master only one ICT tool by choice during the course, but we did not make this strictly mandatory. We tried to kindly motivate the participants to fulfil the two assignments with the support materials and in the consultation with the course instructor rather than strictly prescribing to them what to do and how to learn. They were informed explicitly about their freedom to tailor their learning within the course scenario to their knowledge background, interest, and teaching situations.

Figure 3.8. The Moodle platform for the Dutch course in Cycle 1, including course description, support materials, and consultation forum within the ESTABLISH project’s online environment.

3.3 Instruments for data collection and analysis

We adapted and developed instruments for collecting and analysing data with respect to the research framework for the case studies in the Netherlands, Slovakia, and Vietnam. Table 3.5 shows which instruments were used in each evaluation cycle of the course in the three countries. With these instruments, data were collected from a variety of sources (e.g. questionnaires, observations, reports, and test) and by different data collectors (i.e. the researcher, the course instructor, course participants). Data about the ICT in IBSE lesson were analysed independently by the researcher, an experienced science-education researcher, and the participant as designer and teacher of such lesson. After that, the researcher’s analysis of the ICT in IBSE try-out was compared with self-evaluation of the participants. The use of multiple methods for data collection and analysis enabled us to record both intended consequences and realise possibly unintended ones as the course was implemented. Moreover, findings from one method can be compared and contrasted with those from another. For example, the researcher’s observations of the classroom try-outs (O2) were compared with the self-evaluation report of the participants (R3) and combined with interviews with the participants (C) after the try-out. Data from one method that involves different collectors (i.e.
observations of live sessions by the researcher – O1 and the course instructor – O3) were also compared to each other. These allowed validating data through triangulation (Denscombe, 2000). Consequently, the evaluation of the course would be based on not only each instrument but also data triangulation. While collecting data with these instruments, we endeavoured to record specific cases regarding participants’ activities and feedback; these cases would be then used as vignettes for data analysis and in publications.

Table 3.5. Instruments for data collection and analysis in different cycles of the course in the Netherlands, Slovakia, and Vietnam.

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Cycles of course evaluation*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NL</td>
</tr>
<tr>
<td>Q1: Pre-course questionnaire**</td>
<td>✓</td>
</tr>
<tr>
<td>Q2: Post-course questionnaire</td>
<td>✓</td>
</tr>
<tr>
<td>Q3: Follow-up questionnaire</td>
<td>✓</td>
</tr>
<tr>
<td>O1: Observations of live sessions by the researcher</td>
<td>✓</td>
</tr>
<tr>
<td>O2: Observations of classroom try-outs by the researcher</td>
<td>✓</td>
</tr>
<tr>
<td>O3: Observations of live sessions by the course instructor</td>
<td>✓</td>
</tr>
<tr>
<td>R1: Report on practice with the ICT tool (Form 1)</td>
<td>✓</td>
</tr>
<tr>
<td>R2: Report on the ICT in IBSE lesson plan (Form 2)</td>
<td>✓</td>
</tr>
<tr>
<td>R3: Report on the ICT in IBSE try-out (Form 3)</td>
<td>✓</td>
</tr>
<tr>
<td>I: Inquiry-analysis Inventory</td>
<td>✓</td>
</tr>
<tr>
<td>T: Computer performance test</td>
<td>✓</td>
</tr>
<tr>
<td>C: Communication records</td>
<td>✓</td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates which instruments were used in each evaluation cycle of the course in the Netherlands (NL), Slovakia (SK), and Vietnam (VN).

(**) The complete English versions of questionnaires can be found in Appendix C; Forms 1-3 in Appendix B; Computer test in Appendix D.

We will clarify which, when, and how instruments were used and combined to collect and analyse data to address the particular evaluation questions in Sections 3.4 (research frameworks for Dutch, Slovak, and Vietnamese case studies). In this section, we focus on briefly describing each instrument itself.

3.3.1 Pre-course, post-course, and follow-up questionnaires

The three questionnaires were designed to collect self-reports and opinions of participants about the scenario, support materials, and their activities during and after the ICT in IBSE course. Based on the evaluation questions and the research frameworks (see Sections 3.4 and 3.5), we defined what information to ask the participants. After that, we formulated questionnaire items and then discussed with two experienced science-education researchers about whether each item would collect the intended information. The questionnaires for Dutch participants were in English; those for Slovak and Vietnamese participants were translated into the local language by the local course instructor. The translation was double-checked by a colleague of the local instructor. The English version of these questionnaires can be found in Appendix C.

To collect the input information about participants’ experience, opinions, and interest, we designed the pre-course questionnaire (10 items, Q1). It was administered digitally a week before the course, and the participants had to respond before Session 1. To collect the output information about participants’ experience and opinions on the course, we
designed the *post-course questionnaire* (19 items, Q2). To compare pre- and post-information, we repeated five items from the pre-course questionnaire in the post-course questionnaire. The *post-course questionnaire* was administered digitally right after the course, and the participants had to respond within a week. Before being used for the course evaluation, the pre-course and post-course questionnaires were tried out in the study within the ESTABLISH ICT workshop (see Section 3.1.3). After that, we refined questionnaire items. Additionally, we included at the end of the pre- and post-course questionnaires an open question “Are there any questions above which could be easily misunderstood? If so, please suggest a better formulation below”. After each cycle of the course evaluation, we slightly reformulated some questionnaire items considering the feedback of participants and the revisions of the course scenario.

We designed the follow-up questionnaire (11 items, Q3) to a) collect evidence whether the participants actually studied the ICT tools further and tried out more ICT in IBSE lessons with pupils after the course and b) get the participants’ evaluations on the course and its effects after a relatively long time (e.g. 0.5 to 2 years). It was administered digitally to the three Dutch participant groups in the three first cycles, to the two Slovak participant groups in the two cycles, and to the Vietnamese group (Table 3.5). Ideally, the follow-up questionnaire should have been administered one year after each cycle. We just realised the needs of the follow-up questionnaire after Cycle 3 of the Dutch course and delivered it to all Dutch, Slovak, and Vietnamese participants at the same time. Therefore, durations between finishing the course and receiving the follow-up questionnaire were different to different groups of participants. For example of the Dutch course, it was one year after the course to Cycle-3 participants; one and a half years to Cycle-2 participants; two years to Cycle-1 participants.

### 3.3.2 Observations of live sessions and classroom try-outs

*a) Observations of live sessions by the researcher (O1) and by the course instructor (O3)*

The researcher observed live sessions of the course in the Netherlands and Vietnam and took notes plus video records of such sessions (O1). The Dutch, Slovak, and Vietnamese course instructors were asked to take notes on live sessions (O3). The Slovak course instructor, furthermore, was asked to write structured and extensive observation reports and to record videos of live sessions, considering that the researcher was not present in Slovakia to observe all live sessions. The researcher only observed the final live session of the Slovak course in Cycle 2.

The researcher and the course instructor followed the programme for intended activities and timing (e.g. Table 3.3) and took notes on each activity regarding the following aspects:

- Were the participants engaged in the activity actively?
- Was the activity implemented as intended regarding both timing and content coverage?
- Were the participants on task?
- What were problems for participants? Why did such problems occur?

These aspects were elaborated in an observation scheme for the researcher and the course instructor. Video segments add to observation notes. Based on observation notes and reports,
the researcher and the course instructor discussed directly after each live session about a) how the session was implemented, b) what were deviations from the course scenario, and c) how to improve the scenario for next cycles (Dutch and Vietnamese case studies). For the Slovak case study, this was done via email.

b) Observations of the classroom try-outs by the researcher (O2)

The researcher tried to observe as many try-outs of the Dutch and Vietnamese participants as possible. For the try-outs that the researcher was not able to observe, the participants were asked to capture videos of the classroom activities. Similar to observing the live session, the researcher followed the lesson plan of the participant (Form 2) and took notes plus video record of each phase. The researcher had to review the ICT in IBSE lesson plan in advance to understand the inquiry opportunities that the participants operationalised in each phase of the lesson. The focus of the classroom observation was on the following aspects:

• Did the teacher actually offer the operationalised inquiry opportunities to pupils?
• Were majority of pupils engaged in the provided inquiry opportunities?
• How did the participants manipulate the tool and/or support their pupils’ manipulations of the tool?

Additionally, the researcher would keep an open mind for unexpected problems of the teacher in stimulating, guiding, and managing pupils to exercise inquiry practices during experimentation/modelling activities, using the ICT tool.

The participant as the teacher of the ICT in IBSE lesson was another observer of the classroom try-out. They had to take notes during the lesson in order to later on a) write a self-evaluation report (Form 3) and b) present in the last live session to the course instructor and peers about their ICT in IBSE try-out. Observations of the researcher about the try-out could be then compared and contrasted with the self-observations of the course participants.

3.3.3 Reports of participants regarding main activities outside live sessions

Three main activities of the course participants outside live sessions were a) practicing ICT skills, b) designing the ICT in IBSE lesson, and c) carrying out and self-evaluating the ICT in IBSE try-out (Table 3.3). Forms 1, 2, and 3 as presented in Section 3.1.4 were to support participants to report about these three activities (i.e. assignment reports). After filled out by the participants, the three forms became sources of data, and the three forms functioned as data-collection instruments. In addition to the three forms, for the reports the participants had to attach materials that were produced by the participants and their pupils as results of these three activities.

In particular, the report on practice with the ICT tool (R1) included Form 1 and participants’ Coach result files, which resulted from the practice with the Coach tutorial activities. The report on the ICT in IBSE lesson plan (R2) included Form 2, the Coach activity prepared for the lesson, and other lesson materials if applicable (e.g. pupils’ worksheet, presentation slides). The report on the ICT in IBSE try-out (R3) included Form 3, the video of the try-out, and pupils’ learning outcomes in the form of materials if applicable (e.g. filled-out worksheets and Coach result files). Based on R2 and R3, we could define and record basic information about each ICT in IBSE lesson. For example,

• Topic of the lesson: was it in or out of the curriculum?
• Class/age and number of pupils; time for the lesson.
• Context of the lesson: was it a regular theory/laboratory lesson, an optional lesson of a small group (2 to 10 pupils), or a research project of pupils?
• Learning objectives of the lesson.
• Which ICT tool was used? Was there pre-training about the ICT tool?
• Familiarity of pupils with the ICT tool and inquiry learning before the lesson.

Together with the researcher’s observation of the classroom try-out (O2), R2 and R3 provided information to evaluate the ICT in IBSE objective of the course (see Section 3.4.3).

3.3.4 Inquiry-analysis inventory

We developed an inquiry-analysis inventory that a) defines the 22 categories of inquiry practices operationally (see Chapter 2, Table 2.3) and b) clarifies rules for analysing and coding the ICT in IBSE lesson with respect to these categories (e.g. Table 3.6). Like the LAI (see Chapter 2, Section 2.2.2), the inquiry-analysis inventory can be used to analyse both the lesson plan and the classroom activities. However, coding the lesson plan with this inventory will make use of not only written laboratory instructions as the LAI but also the lesson plan and other lesson materials (e.g. Coach activity and presentation slides). The ICT in IBSE lesson might take place in the various contexts such as regular lessons, interactive demonstrations, practical work, pupils’ research projects, and extracurricular activity of a group of pupils. In such contexts, written laboratory instructions (e.g. worksheets) are not always necessary, or such worksheets just reflect part of teacher’s intention for the ICT in IBSE lessons.

Table 3.6. Operational definition of Category 3.5 within the inquiry-analysis inventory for the ICT in IBSE lesson and the rule for analysing and coding it.

<table>
<thead>
<tr>
<th>The category applies when</th>
<th>The category does not apply when</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils explain the relationships inferred from the experiment by reflecting on the known theory.</td>
<td>- The teacher constructs explanations about the relationships.</td>
</tr>
<tr>
<td></td>
<td>- No explanation about the relationships is asked.</td>
</tr>
</tbody>
</table>

Examples of teacher’s instruction that provides the opportunity for pupils to exercise this category of inquiry practices:
- Do your observations agree with Newton’s second law? Explain.
- Why is there such a large difference in kinetic energy?

In a pilot study, we used this inventory to analyse and code five ICT in IBSE lesson plans. The analysis and coding were carried out independently by the researcher and an experienced science-education researcher. The two coders then compared their coding results,
discussed mismatches, and clarified uncertain cases in coding particular categories. Finally, the two coders together refined operational definitions of each category of inquiry practices and the related coding rule. For example, the two coders had the most mismatches on the original LAI categories:

1.4 - Design observation, measurement, or calculation procedure
1.5 – Design experiment

After discussing these mismatches and uncertainty in coding, the two coders together reformulated these two categories as one category: design of the experiment; this has three sub-categories corresponding to three steps of the experiment design as follows:

1.3a – Define variables and a conceptual setup of the experiment
1.3b – Define how each variable will be observed or measured in the experiment (operational definitions)
1.3c – Define procedures to analyse observation and/or measurement data

After that, another subsample of 10 ICT in IBSE lesson plans was coded by the two coders independently, and mismatches between their coding results (e.g. about Categories 1.3a, 1.3b, 1.3c) this time were less than before. A more detailed description of the 22 categories and ground rules for using the inquiry-analysis inventory can be found in Appendix A. In Section 3.4.3, we describe how this inquiry-analysis inventory was used by the researcher to analyse the IBSE intentions of the lesson plans and actual IBSE implementation.

### 3.3.5 Computer performance test

We had to measure participants’ mastery to operate the ICT tool as a course objective. To evaluate this objective in the first three cycles in the Dutch context, we analysed data from a) pre- and post-course questionnaire, b) observations of participants’ manipulations with the ICT tool in live sessions and in the classroom, and c) records about problems of participants in learning the ICT tool and in preparing the Coach activity for the ICT in IBSE lesson (see Section 3.4.3). After Cycle 3 of the Dutch course, we decided to develop a computer performance test, which would add strong evidence to the conclusion regarding the ICT-mastery objective. The test was developed, tried out, and formally used in Cycle 4 of the Dutch course, in Cycle 2 of the Slovak course, and in the Vietnamese course.

The computer test was offered in the final session of the course to evaluate ICT skills of participants through problem-solving performance tasks with the computer. To design the test, we first reviewed similar tests, using the Coach tools but for pupils, which were developed within the COMPEX project in the Netherlands from 2003 to 2010 and which have been used in the national central examination for school physics. After that, based on the format of the COMPEX test and the TCK problems of the participants recorded in Cycles 1, 2, and 3 of the Dutch course, we developed three incomplete or problematic Coach activities corresponding to the three tools and used them to design troubleshooting tasks:

- **Data-logging task**: problems with a sound-signal graph from a tuning fork
- **Video-measurement task**: problems with energy-time graphs resulting from video measurement of a pendulum
- **Modelling task**: incomplete model of a harmonic motion
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Table 3.7. Summary of the video-measurement task of the computer test: questions and solutions.

<table>
<thead>
<tr>
<th>Task description and questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Given in the folder of the test package, Task2b is a video measurement activity which is to investigate conservation of mechanical energy of a pendulum bob. The video frame-rate is 120 frames per second. The bob is 40 g. The ruler in the video shows the real scale: the minor unit is 1 cm; the major unit is 10 cm (Figure A).</td>
</tr>
</tbody>
</table>

Figure A. Indication of the major unit (10 cm) of the ruler in the video.

Figure B shows obtained graphs of Ek (kinetic energy), Ep (potential energy), E (mechanical energy) over time, which look wrong. Open the result file Task2b to examine it in detail.

Figure B. A screen-shot of a Coach activity (Task2b), which currently yields a wrong result.

a) What makes the graphs looking wrong?
b) What are the problems in this activity? How to fix?

Execute your solutions and then save the result as a new file, named Task2b-fixed.

Note. If you have not been successful in fixing the problems yet, still save your work and submit it, so we will know how far you go.

Solutions

a) What makes the graphs looking wrong?
- The mechanical-energy graph does not look like a horizontal line (perhaps slightly inclined downward) as expected from theory.
- Two data points do not fit the general trends which are drawn with many other data.

b) What are the problems in this activity? How to fix?
- Time calibration is not set yet. Change it to 120 (frames per second).
- Scale calibration is wrong. Input number 0.5 m does not match with the indication of real 0.6 m on the frame. Change the input to 0.6 m.
- Two times the user clicked on the edge of the bob instead of the center as many other times. Choose the Scan function on the graph, click on the wrong data point, and then drag it to the bob center.
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Based on these three Coach activities, we designed the three test packages; each package included a) a task description coupled with the Coach activity, b) an answer-template for participants, and c) a solution and grading scheme for the course instructor. Time intended for a package was 20 minutes. Within the 20 minutes, the participants would probably take the most time to determine problems and define solutions; actual execution of the right solution would take three minutes at most. The performance tasks were focussed on testing participants’ skills to troubleshoot problems of experimentation/modelling activities (TCK) rather than testing skills related to isolated technical details (TK). This is illustrated in Table 3.7, which summarises the video measurement task and its solutions. Additionally, we considered the participant doing the test as a teacher who is preparing the Coach activity for her or his class, not as a learner of an ICT course; they could use any types of references. The only strike rule was: to do the test independently in order for us to evaluate the individual participant’s ability. The course instructor was present to keep the participants doing independently, to help them as needed, but not to provide any hints for solutions.

The researcher discussed these performance tasks with a science-education researcher and a Coach expert and refined the tasks considering the following issues:

- Did the performance task really test what we intended to test?
- Were the descriptions of the task understandable?
- Were the solutions correct and sufficient?
- Was the timing of the test appropriate?

The computer performance test for Dutch participants (Cycle 4) was in English; those for Slovak and Vietnamese participants were translated into the local language by the local course instructor. A colleague of the local instructor, who had experience with Coach, was asked to do the test to check the timing, to define hurdles in understanding the task, and to refine the task descriptions in the local language. The English version of the three packages of the test can be found in Appendix D.

3.3.6 Communication records

To get insight into the process of participants learning and applying ICT in IBSE and possible difficulties during the course, we took initiatives to elicit and record participants’ formative feedback through the following communication forms:

- Online consultation between the participants and the course instructor: information about participants’ problems in learning ICT tools and in preparing the Coach activity for the ICT in IBSE lesson;
- Interviews with the participants before and after live sessions and classroom try-outs: information about rationale behind decisions that the participants took during the course (e.g. the tool to specialise in, the topic of the lesson);
- Coordination emails between the participants and the course coordinator: information about progress of individual assignments and obstacles for participants in carrying out these assignments.
3.4 Research design and evaluation framework

3.4.1 Design of the cyclic research

In this section, we present the design of the cyclic research, which included the three case studies about the course in the three countries. These three case studies were related; the Dutch case study was the earliest and most extensive, followed by the Slovak case study, then the Vietnamese case study. All three case studies a) concerned the same questions about validity of the pedagogical principles, usefulness of the support materials, and attainment of the course objectives, b) applied a similar evaluation framework, and c) used similar instruments for data collection and analysis. We describe commonalities and differences among designs of the three case studies in the following sub-sections.

a) The Dutch case study

The Dutch case study concerned the main research and development of the ICT in IBSE course, including four cycles of implementation and evaluation of the course. Considering the Dutch context of a pre-service course for physics/chemistry teachers, we further operationalised the pedagogical principles in the initial scenario (Figure 3.6) with respect to the four objectives of the ICT in IBSE course. The support materials for this scenario were selected or developed (Table 3.1). The research aspect of the Dutch case study concerned the following questions:

A. To what extent were the four pedagogical principles implemented as intended?
B. To what extent did the course achieve its four objectives?

Question B involves the evaluation of the course’s effects on participants, which resulted from actual implementation of the pedagogical principles. The evaluation of this implementation was guided by Question A.

Following the design research approach, we first ensured sufficient implementation of the pedagogical principles, and then evaluated the effectiveness of the course in the Dutch context. The sufficient implementation of the principles was dependent upon not only their validity but also practical conditions regarding the course scenario (incl. live sessions, individual assignments, and online support) and support materials. Among the four cycles of the ICT in IBSE course in the Dutch case study, Cycles 1 and 2 were focussed on optimising the course scenario and the use of support materials. We expected to achieve faithful implementation of the four principles in Cycle 3, and so in this cycle, we would focus on evaluating summative effects of the Dutch ICT in IBSE course (i.e. achievements of the four course objectives). Attainments of the course objectives were evaluated in Cycles 1 and 2 as well; these evaluations contributed to revisions of the course scenario in the sequential cycle. The robustness of the pedagogical principles (ecological validity) and effectiveness of the course were tested in Cycle 4 of the Dutch course under routine implementation conditions without the extra support of the researcher. In Chapter 4, we will present the full design process of the Dutch ICT in IBSE course.

b) The Slovak and Vietnamese case studies

The Slovak case study concerned the adaption, optimisation, and evaluation of the ICT in IBSE course in the Slovak context of in-service teacher training through two iterative
cycles. Cycle 1 of the Slovak case study was focused on optimising the initial scenario of the Slovak ICT in IBSE course (Cycle 1) towards a more optimal one in Cycle 2. Summative effects of the Slovak course were evaluated in Cycle 2. The two cycles of the Slovak course were already in routine implementation conditions without the direct participation of the researcher, so the robustness test was not necessary. The Vietnamese case study concerned adaption and evaluation of the Vietnamese ICT in IBSE course, which was implemented within a Master programme on physics education. Considering the local context, the scenario of the Vietnamese course was adapted from the general design of the course and evaluated in only one cycle. In Chapters 5 and 6, we will first describe the local context of the ICT in IBSE course in Slovakia and Vietnam. Next, we will clarify:

• how we adapted the general design of the ICT in IBSE course (i.e. course objectives, pedagogical principles, support materials) to the certain scheduling requirements and boundary conditions in Slovakia and Vietnam;
• how we applied the evaluation framework and instruments presented in this chapter for the Slovak and Vietnamese case studies.

Finally, we will present results of these two case studies and discuss effectiveness of the ICT in IBSE course; usefulness of the support materials; validity and generalizability of the pedagogical principles; and transferability of the course design in the Slovak and Vietnamese contexts. Considering that evaluation and revisions of the Cycle-1 scenario were reported in Jeskova, Tran, Kires, and Ellermeijer (2015b), in Chapter 5 we will focus on presenting the Cycle-2 scenario of the Slovak course and its summative effects.

3.4.2 Design of a case study for evaluating and optimising the course

In the following paragraphs, we take the most extensive case study (i.e. the Dutch case study) to describe the design for evaluating and optimising the ICT in IBSE course. This design was also applied for the Slovak case study, except the robustness test. It was applied to the Vietnamese case study, except the robustness test and the optimisation framework.

a) Formative evaluation and optimisation of the course through iterative cycles

Formative evaluations of the Dutch course through the first three cycles were focused on implementation of the four pedagogical principles and support materials. These evaluations were guided by the following sub-questions of Question A:

Question A1: Was the “one theory-practice cycle” principle implemented faithfully?
Question A2: Was the “distributed learning” principle implemented faithfully?
Question A3: Was the “depth first” principle implemented faithfully?
Question A4: Was the “ownership of learning” principle implemented faithfully?
Question A5: Were the support materials useful for participants?

The basis of evaluations regarding faithful implementation was a comparison between the intended scenario and the actual activities of participants during the course. In Section 3.4.3, we describe which and how the instruments for data collection and analysis (Table 3.8) were used and combined to address these questions in each cycle of the course.

Operationization of the pedagogical principles and intended use of support materials in the initial scenario of the Dutch course would possibly not yet be implemented faithfully in
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Cycle 1. The formative evaluation (Questions A1 to A5) together with a) evaluations of the course objectives and b) experiences with the course would suggest revisions of the course scenario (i.e. live sessions, individual assignments, and online support). These revisions were aligned with the pedagogical principles and aimed at more faithful implementation of the course in Cycle 2. The Cycle-2 evaluations of the course would possibly result in positive effects on certain aspects and in not-good-enough effects in other aspects. Concerning the aspects on which expected effects were not realised yet, we continued to optimise the course toward a more optimal version in Cycle 3 (Figure 3.9). In Chapter 4, Section 4.2, we will describe the actual optimisation of the Dutch course. Furthermore, we will discuss the findings regarding practical conditions for each principle to be implemented faithfully.

Figure 3.9. Optimisation of the Dutch ICT in IBSE course through three cycles and the robustness test of the course.

b) Summative evaluation of the ICT in IBSE course

To evaluate summative effects of the Dutch course in Cycle 3, we measured attainments of the four course objectives (see Chapter 2, Table 2.5). These evaluations were guided by the following sub-questions of Question B:

Question B1: Did the course achieve its awareness objective?

Question B2: Did the course achieve its ICT mastery objective?

Question B3: Did the course achieve its ICT in IBSE objective?

Question B4: Did the course achieve its motivation objective?

To address each question, we first operationalised levels of each objective attainment. The definition of these levels was based on theoretical considerations and aligned with time-constraint conditions of the course. Next, we indicated and rationalised our expectation about a certain attainment level for each objective. Subsequently, we defined which and how instruments were used and combined to collect sufficient data regarding the objectives (Table 3.8). We will describe these in Section 3.4.3.

c) Robustness test

After Cycle 3 of the Dutch ICT in IBSE course, we implemented and evaluated the fourth course in the regular context of a normal teacher-education course to test for robustness. This robustness test was focused on the transition from the experimental Cycle-3
version to the routine version of the course in Cycle 4. In Cycles 1, 2, and 3, in addition to collecting data during the course, the researcher was in charge of coordinating the course: doing logistics, communicating participants for pre-course preparation, making different course instructors clear about their different roles in the course, and tracking progresses of participants’ individual assignments. In Cycle 4, all of these coordination activities were handed over to the course instructor. This Cycle-4 course was not considered as part of the optimisation of the course. Rather, it was in the phase of testing the robustness of the optimised Dutch course (Cycle 3) in the regular context as a developed educational product.

We addressed the following questions through the test:

- Were the pedagogical principles still valid in the Dutch regular context?
- Did the positive outcomes in Cycle 3 still show up in Cycle 4 without the extra inputs of the researcher?
- Could the coordination activities of the researcher be safely transferred to the course instructor in Cycle 4?

In Chapter 4, Section 4.4, we will present this robustness test and its outcomes in more detail.

d) Expected outcomes of the Dutch case study

After the Dutch case study, we would a) conclude whether the four pedagogical principles worked in the Dutch context and whether the ICT in IBSE course could achieve its objectives and b) arrive at an effective scenario of the ICT in IBSE course in the Dutch context. We would understand: how did the pedagogical principles work? what were the difficult points? why? Consequently, we will discuss theoretical implications regarding these four pedagogical principles. In Chapter 4, we will finally answer the first overarching research question of the research project: what are characteristics of an effective, short course for Dutch student teachers to learn to apply ICT tools for data logging, video measurement, and modelling in inquiry-based science education?

e) Expected outcomes of the Slovak and Vietnamese case study

The main aims of these two case studies were to test the attainments of the four objectives of the ICT in IBSE course, the validity and generalizability of the four pedagogical principles, and the transferability of the actual course design in different countries and different settings. Moreover, with these case studies we were also concerned about the following questions:

- What adjustments of the ICT in IBSE course had to be made for the Slovak and Vietnamese contexts?
- What were differences in the summative effects of the three versions of the ICT in IBSE course? How were these differences related to differences in the local contexts of the course?
- For the Vietnamese case, what are the challenges and potential solutions to the application of IBSE in a hierarchical education culture?

After discussing results of Dutch, Slovak, and Vietnamese case studies in Chapters 4, 5, and 6, we will finally answer the second overarching research question of the research project in Chapter 7: to what extent is this course applicable in different educational and cultural
contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam)?

3.4.3 Evaluation framework

This section presents the evaluation framework of a case study. We also take the Dutch case study to describe the framework for evaluating the ICT in IBSE course. In this evaluation framework, we define the criteria to evaluate the implementation of the pedagogical principles and support materials and pre-define the attainment levels of the course objectives (Dutch context). We summarise here which and how instruments were used and combined to collect and analyse data for each evaluation question (Table 3.8). In Chapter 4, Sections 4.2 and 4.3, we describe these methods in detail per each evaluation question, present the collected data, compare the data-analysis outcomes with the evaluation criteria and the expected attainment level, and conclude the evaluation aspect.

A1: Was the “one theory-practice cycle” principle implemented faithfully?

To address this question, we evaluated whether or not the participant can complete each stage of one theory-practice cycle at the intended moment of the course scenario (Table 3.3) as follows:

- completing the Coach activity for the ICT in IBSE lesson plan within Session 2;
- completing the lesson plan (incl. the Coach activity and the learning scenario) between Sessions 2 and 3;
- completing the classroom try-out of the lesson plan before Session 3;
- completing the self-evaluation report of the classroom try-out before Session 3.

Based on participants’ assignment reports (R2, R3) and the observation of Sessions 2 and 3 (O1), we recorded when each participant finalised each of these four stages and compared the records to the intended moment. Moreover, to understand possible obstacles for carrying out the complete cycle, we would ask participants in Sessions 2 and 3, via email, and after the try-out (C).

A2: Was the “distributed learning” principle implemented faithfully?

To address this question, we evaluated the following aspects:

1. Were available time and format of live activities sufficient for participants?
2. Was the online support helpful for participants’ learning outside live sessions?
3. Did the participants spend sufficient time outside live sessions?
4. Did the participants appreciate the distributed learning scenario?

About the first aspect, we took notes about actual time spent for each live activity (O1, O3) and compared with the intended programme. Via the post-course questionnaire (Q2) and in Session 3 (O1, O3), we asked the participants to evaluate the timing and effects of the live activities and to suggest refinements of these activities for the sequential cycle. About the second aspect, we checked the Moodle and email log whether the participants made use of the online platform and online consultation (C). Via the post-course questionnaire (Q2), we asked the participants to evaluate usefulness of the online platform and the online consultation with the course instructor. Moreover, to understand possible obstacles in consulting the course instructor via the Moodle forum and email, we questioned the participant after the classroom
try-out (C). About the third aspect, we asked the participants in Session 1 how much time they spent for the pre-course preparation (C). In assignment reports (R1, R2, R3), the participants had to estimate how much time they spent for individual assignments. We did not prescribe how much time participants had to spend on completing each activity outside live sessions. Consequently, participants' self-estimates reflected the actual time, which was then compared with the time anticipated for learning outside live sessions. About the fourth aspect, we asked the participants via the post-course questionnaire whether they preferred the distributed scenario of the course as compared with a compact Coach workshop (Q2).

Table 3.8. Overview of instruments per evaluation question.

<table>
<thead>
<tr>
<th>Evaluation questions</th>
<th>Instruments*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1: Was the “one theory-practice cycle” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A2: Was the “distributed learning” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A3: Was the “depth first” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A4: Was the “ownership of learning” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A5: Were the support materials useful for participants?</td>
<td>✓</td>
</tr>
<tr>
<td>B1: Did the course achieve its awareness objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B2: Did the course achieve its ICT mastery objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B3: Did the course achieve its ICT in IBSE objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B4: Did the course achieve its motivation objective?</td>
<td>✓</td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates which instruments were used for each question. These indications (e.g. Q1, O2, R3) are mentioned in descriptions about how to address each question. This use of instruments was applied for evaluations in all four cycles of the Dutch course, except that computer test (T) was used only for Cycle 4, and follow-up questionnaire (Q3) and observation of the classroom try-out (O2) were not used for Cycle 4.
A3: Was the “depth first” principle implemented faithfully?

To address this question, we evaluated the following aspects:

1. Did the participants follow the one-tool specialisation?
2. Could the participants learn the ICT tool in depth?
3. After learning one tool in depth, were the participants confident to learn other tools by themselves?

About the first aspect, for each participant, we recorded which tool was chosen in Session 1 (O1), which tool was practiced in Assignment 1 (R1), which tool was used for the ICT in IBSE lesson (R2). After that, we checked whether the individual participant chose only one tool to learn and apply or not. To understand why the individual participants did possibly not specialise in only one tool, we questioned them at the end of live sessions or via email (C). About the second aspect, we evaluated if they achieved the mastery that would enable them to design a new Coach activity or at least modify the given Coach activities. Based on the submitted lesson plan (R2), we examined if the Coach activity was selected or modified from the given one or totally new. To understand possible difficulties of the participants in learning the ICT tool, we recorded a) the questions of participants to the course instructor in live sessions (O1, O2) and via the online consultation (C) and b) the difficulties described in their assignment reports (R1, R2). After the classroom try-out, we questioned the participants about their difficulties in preparing the Coach activity for the ICT in IBSE lesson plan (C). Additionally, via the post-course questionnaire (Q2), we asked the participants to evaluate effects of live instruction about the ICT tool. About the third aspect, via the post-course questionnaire (Q3), we asked participants whether they were confident in learning the ICT tools in which they did not specialise during the course.

A4: Was the “ownership of learning” principle implemented faithfully?

To address this question, we evaluated if the participants did tailor and pursue their own learning during the course and if they found what they learnt relevant. Via assignment reports (R2, R3), we recorded their choices of the ICT tool to master and of the ICT in IBSE lesson to develop and try out. In live sessions (O1, O3) and after the try-out (C), the participants were asked to account for part of these choices considering their interest, needs, background, and/or teaching condition. Additionally, we observed if the participants worked actively in live group and individual activities (O1, O3) and if they were proactive in preparing the ICT in IBSE try-out in the classroom (C). After the try-out, the participants were asked if they appreciated the relevance of IBSE as integral part of the ICT in IBSE course (C).

A5: Were the support materials useful for participants?

To address this question, via the post-course questionnaire (Q2) we asked the participants to evaluate the usefulness of each support material. Additionally, we observed how the participants made use of the support materials in live sessions (O1, O3) and collected their direct feedback on the use of these materials (C).

B1: Did the course achieve its awareness objective?

Attainment levels and expectations. We concretised attainment of this objective, considering two variables: a) if the participants became aware of benefits of only the ICT tool
they studied in depth or also of other tools and b) for one tool, the participants appreciated its added value sufficiently (two or three benefits) or superficially (one benefit or not at all).

Consequently, the attainment of the awareness objective of the ICT in IBSE course included the following levels:

**Level 1.** Participants could enumerate one relevant benefit of one tool or not at all.

**Level 2.** Participants could enumerate one relevant benefit of each of the three ICT tools

**Level 3.** Participants could enumerate two or three relevant benefits of the ICT tool in which they specialised during the course

**Level 4.** Participants could enumerate two or three relevant benefits of each of the three ICT tools

In Chapter 2, Section 2.1.2, we reviewed the literature and identified main benefits of each ICT tool in regard to different aspects (e.g. authentic learning, inquiry practices, and better understanding). With “relevant” in the definition of these levels, we expected that what the participants enumerated would match with the benefits, which were written in Section 2.1.2. If it did not match, we would analyse each enumerated point and judge if it is relevant, according to our knowledge and experience. We expected that the participants would reach to Levels 2 or 3.

**Data collection and analysis.** Via an open-ended question in the post-course questionnaire (Q2), we asked the participants to indicate educational benefits of the data logging, video measurement, and modelling in science education. After that, we reviewed the responses to examine particular benefits of the ICT tool each participant pointed out. Next, we compared these enumerated benefits to the ones that were discussed in the literature and/or reviewed in Section 2.1.2.

**B2: Did the course achieve its ICT mastery objective?**

**Attainment levels and expectations.** Based on Rogers’s and Twiddle’s (2013) ICT-mastery progression model (see Chapter 2, Section 2.3.1), we defined **levels of the ICT mastery objective** of the ICT in IBSE course as follows:

- **Non-user level.** The participants were not confident to teach with Coach yet.
- **Adopter-user level.** The participants gained basic Coach skills and could **execute the Coach exemplary activities** in the classroom.
- **Adaptor-user level.** The participants gained basic Coach skills and could **modify the Coach exemplary activities** for their classroom try-outs.
- **Creator-user level.** The participants gained basic Coach skills and could **develop their own Coach activities** for their classroom try-outs with a little help of Coach experts.
- **Expert level.** The participants could develop their own Coach activities and trouble shoot problems with Coach on their own.

With this definition, we first considered the question: did the participants achieve basic skills with Coach? “Basic” means starting competence that is sufficient for the participants to learn the Coach tool further and to design and teach an ICT in IBSE lesson, using the Coach tool.
Non-users of Coach do not have this competence yet. Second, we considered whether the participants could create a new Coach activity or at least modify the exemplary Coach activity or just make use of such given activity. This corresponds to the three slightly different levels from high to low: creator-user, adaptor-user, and adopter-user. “Creator-user” is the highest among these three levels, but the creator-user is not an expert of Coach yet. They might still encounter difficulties in developing a new Coach activity from scratch or in fixing problems of an existing Coach activity. Consequently, they sometimes need help from Coach experts. At the expert level, a participant can develop new Coach activities and figure out problems of Coach activities on their own.

Through the pre-course questionnaire and observations of the first live session, we got evidence that the majority of Dutch participants were at the non-user level, and others were at the adopter-level. Almost all Slovak and Vietnamese participants were non-users of Coach. For the ICT in IBSE course, we expected that the participants would reach one of the three levels: adopter-user, adaptor-user, and creator-user, corresponding to the basic skills to operate the Coach tool. Attainment of the expert level would be nice, but not realistic to expect as an outcome of the course.

Data collection and analysis. To evaluate attainment of the ICT mastery objective, we collected data about the following aspects:

- To what extent were the participants confident in manipulating the tool?
- How could the participants manipulate the tool and/or support their pupils’ manipulations of the tool in the classroom?
- Could the participant develop a new Coach activity or at least modify the Coach exemplary activity for the ICT in IBSE lesson?
- Could the participants troubleshoot problems in applying the ICT tool?

Via the pre-course questionnaire (Q1), we asked the participants about their confidence in manipulating each of the three ICT tools. We repeated this question in the post-course questionnaire (Q2). Additionally, we observed the participants’ and/or their pupils’ manipulations of the ICT tool in the try-outs to check a) if these manipulations yielded sufficient experiment/model data and b) if the participants came across and/or troubleshooting problems of the Coach activity in the classroom (O2). Via the report on practice with the ICT tool (R1) and via the email consultation (C) and in Sessions 2 (O1), we checked if the participants encountered and/or solved problems in preparing the Coach activity for the try-out. Based on the submitted lesson plan (R2), we examined if the Coach activity was selected or modified from the given ones or totally new.

The computer test was not used for evaluating the ICT mastery objective in Cycle 3 of the Dutch course, but it was used in Cycle 4 (see Chapter 4, Section 4.4.2). The computer-test results would contribute to the final conclusion about the summative effects of the Dutch course regarding the ICT mastery.

B3: Did the course achieve its ICT in IBSE objective?

In Chapter 2, we defined the requirements for the ICT in IBSE lesson (Section 2.1.3) and clarified the framework for designing, implementing, and evaluating the ICT in IBSE lesson (Section 2.2.2). Within this framework, we focus on the inquiry aspect among many
aspects to evaluate the ICT in IBSE lesson. While designing and implementing the ICT in IBSE lesson, the participants were required to follow the four stages:

Stage 1. In the lesson plan, the participants had to indicate which inquiry skills in the given list of the 22 inquiry categories were aimed as objectives of the ICT in IBSE lesson.

Stage 2. In the lesson plan, the participants had to specify inquiry opportunities within the experimentation/modelling activity.

Stage 3a. In the classroom try-out, the participants had to offer pupils inquiry opportunities within the experimentation/modelling activity.

Stage 3b. In the classroom try-out, the majority of pupils should be engaged in the intended inquiry opportunities within the experimentation/modelling activity.

These stages were used by the participants in designing, implementing, and self-evaluating the ICT in IBSE lesson. The stages were used by the researcher in analysing the lesson plan and observing the classroom try-out to evaluate the ICT in IBSE lesson. Based on this framework, we defined the three components of the ICT in IBSE objective as follows:

1. Ability to design: Could the participants operationalise inquiry opportunities with the ICT tool in the lesson plan?
   
   Aspect 1: Did the participant operationalise inquiry objectives (i.e. inquiry skills) as inquiry opportunities within the experimentation/modelling activity in the ICT in IBSE lesson plan?
   
   Aspect 2: Did the participants specify inquiry opportunities that stimulate back and forth thinking between the physical and theoretical worlds?

2. Ability to implement: Could the participants implement inquiry opportunities with the ICT tool faithfully in the classroom try-out?
   
   Aspect 1: Did the participant offer pupils inquiry opportunities which were operationalised in the lesson plan?
   
   Aspect 2: Was the majority of pupils engaged in inquiry opportunities which were offered by the participant?

3. Ability to evaluate: Could the participants self-evaluate implementation of inquiry opportunities with the ICT tool in their try-out?
   
   Aspect 1. Could the participants evaluate achievement of the lesson’s inquiry objectives, using evidence from the classroom try-out?
   
   Aspect 2. Could the participants indicate what did not go as intended and provide reasons for deviations?
   
   Aspect 3. Could the participants suggest relevant changes of the lesson plan for future implementation in another class?

Expectations for each component of the ICT in IBSE objective. About the ability to design, we expected that the participants would focus on three to seven inquiry skills as inquiry objectives and be able to operationalise most of these objectives as inquiry
opportunities in the lesson plan (Aspect 1). We expected to see in most lesson plans one or two inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7 to be operationalised (Aspect 2). These inquiry categories (1.1 to 1.4, 3.3 to 3.7) stimulate back and forth thinking between the physical and theoretical worlds. These inquiry skills were missing in the laboratory manuals analysed by Tamir and Lunetta (1981).

About the ability to implement, we expected that a half of inquiry opportunities (operationalised in lesson plans) would be realised in the classroom (Aspects 1 and 2). The expectation about just a half of IBSE intentions instead of all was because implementation of an ICT in IBSE lesson requires sophisticated classroom management skills, which not all student teachers achieve in their first years of teaching. About the ability to self-evaluate, we expected that a half of the participants would be able to a) evaluate achievement of their lesson’s inquiry objectives, b) indicate what did not go as intended and why, and c) suggest relevant changes of the lesson plan for future implementation (Aspects 1, 2, and 3).

Data collection and analysis. We gathered data about intended versus actual ICT in IBSE lessons through different sources as follows:

- **Intended ICT in IBSE lesson**: lesson plan (Form 2), the Coach activity, and other lesson materials if applied (e.g. pupils’ worksheet, presentation slides) (R2);
- **Actual ICT in IBSE lesson**: self-evaluation report (Form 3), the classroom video, and pupils’ learning outcomes in form of materials if applied (e.g. filled-out worksheets and Coach result files) (R3); observation notes of the researcher (O2).

Reviewing these data and using the inquiry-analysis inventory (I) with the 22 categories (see Chapter 2, Table 2.3), we analysed and coded each of the four stages for each ICT in IBSE lesson. The coding data and related evidence from the data sources (e.g. intended questions in the lesson plan, the video moment in which pupils’ engagement can be observed) were recorded in the lesson profile as a data sheet per participant or per lesson (each participant designed and tried out a lesson). This profile includes coding data (i.e. checkmark) about which inquiry categories were applied in each of the four stages of intended versus actual ICT in IBSE lesson (Table 3.9).

*Table 3.9.* The profile for each ICT in IBSE lesson of each participant and illustration about how the filled profile looks like with particular checkmarks.

<table>
<thead>
<tr>
<th>Inquiry categories</th>
<th>Intended lesson</th>
<th>Actual lesson</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage 1</td>
<td>Stage 2</td>
<td>Stage 3a</td>
</tr>
<tr>
<td></td>
<td>Inquiry category</td>
<td>Inquiry category</td>
<td>Inquiry opportunity</td>
</tr>
<tr>
<td></td>
<td>aimed at as inquiry</td>
<td>operationalised as</td>
<td>offered by the participant</td>
</tr>
<tr>
<td>1.1</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1.2</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>1.3a</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>1.3b</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* The checkmark “✓” indicates to which inquiry category was applied in each stage.
Based on the coding data (checkmarks), we checked matches among the four stages and then concluded about the three evaluation aspects:

- **Ability to design – Aspect 1**: Did the participant operationalise inquiry objectives (i.e., inquiry skills) as inquiry opportunities within the experimentation/modelling activity in the ICT in IBSE lesson plan? (The match between Stages 1 and 2)
- **Ability to implement – Aspect 1**: Did the participant offer pupils inquiry opportunities which were operationalised in the lesson plan? (The match between Stages 2 and 3a)
- **Ability to implement – Aspect 2**: Were majority of pupils engaged in inquiry opportunities which were offered by the participant? (The match between Stages 3a and 3b)

Based on the coding data for Stage 2, we checked if each participant operationalised inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7 (Ability to design, aspect 2).

Regarding *the ability to evaluate*, in two groups of 4 or 5 participants plus a course instructor within Session 3, the participants reported their try-outs regarding Aspects 1, 2, and 3, using their assignment reports (R2, R3). While monitoring the group discourse, the course instructor ensured the three aspects of this component (Ability to evaluate) to be discussed among participants. In addition to capturing video of the group discussion, we asked the course instructor and a participant in each group to take notes of the discourse (O3). After all, we reviewed the self-evaluation reports (R3) to examine whether or not the participant clearly stated their points of evaluation on the three aspects. Next, we compared participants’ self-evaluation statements with our evaluations of the try-out. Based on videos and notes of the group discussion (O3), we also checked if the course instructor and fellow participants agreed with the participant’s self-evaluation points.

**B4: Did the course achieve its motivation objective?**

**Attainment levels and expectations.** The ICT in IBSE try-out was the core activity of the course, and this try-out was seen as a start of long-term ambition that involves sustainable incorporation of ICT in IBSE in teaching practice. As a result of the course, the participants would believe in their ability; they would know how to learn more and desire to teach more ICT in IBSE lessons after the course. Based on this long-term vision of the course (see Chapter 2, Section 2.1.3), we defined **levels of the motivation objective** of the ICT in IBSE course:

- **Level 1.** During the course, participants might be interested in the ICT tools and ICT in IBSE teaching. However, after the course, they did not devise any plan to study the ICT tools further or to try out more ICT in IBSE lessons.
- **Level 2.** Right after the course, the participants devised plans to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.
- **Level 3.** Relatively long time after the course (0.5 to 2 years), the participants had actually studied the ICT tools further and had tried out more ICT in IBSE lessons with pupils.

We expected that the participants would achieve at least Level 2. We hoped about a half of the participants would achieve Level 3. Just “a half” is because school teaching conditions (e.g., curriculum time, teacher preparation time, availability of ICT) are not
favourable yet, especially in Slovakia and Vietnam. Additionally, for Dutch participants in their first two or three years of teaching, it will be much harder to add extra ICT in IBSE lessons to a full curriculum than for experienced teachers.

Data collection and analysis. To evaluate attainments of the motivation objective, via the post-course questionnaire (Q2), we asked the participants about their plans to apply the ICT tools in their teaching in the near future. Via the follow-up questionnaire (Q3), we asked the participants different questions in different formats in order to collect data about a) whether they actually studied the ICT tools further and tried out more ICT in IBSE lessons with pupils and about b) their motivation at the moment of receiving the follow-up questionnaire (i.e. 0.5 to 2 years after the course).

3.5 Conclusion of this chapter

In this chapter: course design and research design, we presented the frameworks for actual implementation, evaluation, and optimisation of the ICT in IBSE course. The design decisions and methodological frameworks will not be repeated in Chapters 4, 5, and 6. These decisions and frameworks can be summarised as follows:

- Coach platform for data logging with sensors, video measurement, and dynamical modelling was selected, and it was suitable for the ICT in IBSE course (see Section 3.1.1).
- Coach support materials and Forms 1, 2, and 3 for individual assignments were selected and developed as support materials of the ICT in IBSE course (see Section 3.1.4, Table 3.1).
- Initial scenario of the ICT in IBSE course in the Dutch context was clarified; this scenario reflects explicit operationalization of the four pedagogical principles with respect to the four course objectives (see Section 3.2.1, Figure 3.6, Table 3.3).
- The instruments used for evaluating the ICT in IBSE course were developed, tried out, and described in Section 3.3.
- The general design of the Dutch, Slovak, and Vietnamese case studies for evaluating and optimising the ICT in IBSE course was described in Sections 3.4.
- The evaluation framework for a case study summarises which and how instruments were used and combined to address each evaluation question (see Section 3.4.3).
Chapter 4 Implementation, evaluation, and optimisation of the Dutch ICT in IBSE course

The initial scenario of the Dutch course, the support materials, the instruments for data collection and analysis, and the research framework of the Dutch case study were presented in Chapter 3. This chapter 4 presents actual implementation, evaluation, and optimisation of the Dutch version of the ICT in IBSE course\(^1\). In Section 4.1, we summarise the research questions and methodology of the Dutch case study and then describe the characteristics of the Dutch participants and the boundary conditions of the Dutch ICT in IBSE course. Next, Section 4.2 concerns how the course was revised after Cycles 1 and 2 toward a more optimal version in Cycle 3. The revisions of the course scenario after a cycle were based on problems found in the evaluation of the course and aimed at more faithful and effective implementation of the course in the sequential cycle. Section 4.3 focuses on evaluations of the course outcomes according to the four course objectives. Section 4.4 reports about the robustness of the course in Cycle 4 delivered in the regular situation. In Section 4.5, we a) conclude the effectiveness of the Dutch ICT in IBSE course and the validity of the four pedagogical principles in the Dutch context, b) discuss theoretical implications, and c) answer the first overarching research question of the present research.

4.1 Background, context, and methodology

4.1.1 Summary of the explorative phase of the research project

The Dutch case study was to address the first overarching research question:

*What are characteristics of an effective, short course for Dutch student teachers to learn to apply ICT tools for data logging, video measurement, and modelling in inquiry-based science education?*

We applied the design research approach to develop the short ICT in IBSE course and simultaneously understand its core characteristics: objectives and pedagogical principles. Based on the literature study (see Chapter 2, Sections 2.1, 2.2, and 2.3), we elaborated the general aim of the ICT in IBSE course to the four concrete objectives. Considering these objectives and the general time-constraint condition of the course, we studied the literature and defined four pedagogical principles (see Chapter 2, Section 2.4.2, Table 2.6). In order to prove the effectiveness of the ICT in IBSE course and the validity of the pedagogical principles in the Dutch context, we had to address the two evaluation questions:

A. *To what extent were the four pedagogical principles implemented in the Dutch context as intended?*

B. *To what extent did the Dutch ICT in IBSE course achieve its four objectives?*

We applied the evaluation framework, which was developed and described in Chapter 3, Section 3.4.3. This framework was for a) evaluating implementation of the four

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\(^1\) An earlier, shorter version of this chapter has been presented in 2014 as a paper at the GIREP-MPTL 2014 conference and published after peer review as Tran, van den Berg, Ellermeijer, and Beishuizen (2015).
pedagogical principles and optimising the course scenario through iterative cycles, b) evaluating the course outcomes with respect to the four objectives, and c) testing the robustness of the course in the regular context. *Instruments and data-analysis schemas used in this framework were described in Chapter 3, Sections 3.3 and 3.4.* Based on this research framework, we present and discuss a) the formative evaluation and optimisation of the course in Section 4.2, b) the summative evaluation of the course in Section 4.3, and c) the robustness test in Section 4.4. The structure of Sections 4.2 and 4.3 is consistent with that of the evaluation framework presented in Chapter 3, Section 3.4.3.

In the following sub-sections of Section 4.1, we describe the characteristics of the Dutch context and the boundary conditions of the Dutch ICT in IBSE course. Next, we explain how we considered this Dutch context and boundary conditions while operationalising the pedagogical principles in the initial scenario of the course (Cycle 1) as described in Chapter 3, Section 3.2.

### 4.1.2 How did we invite participants involved in the Dutch case study?

In the Netherlands, nine research universities offer a one-year post-graduate physics/chemistry teacher-education programme. Graduates of this programme are certified to teach at all levels of secondary education. The Dutch ICT in IBSE course was offered jointly by four out of these nine universities (i.e. VU, UU, UvA, and TU-Delft) within the teacher-education programme (Table 4.1). We invited the student teachers (also called pre-service teachers or teacher-education students) involved in the course through the following steps. First, we introduced the ICT in IBSE course and our associated study to teacher educators at the Dutch universities. The teacher educators then checked whether it was possible to integrate the course in the existing teacher-education programme. If possible, they would recommend the course for their student teachers to enrol. Upon fulfilment of the course requirements, the student teachers would be rewarded with credit points.

*Table 4.1. Number of Dutch student teachers participating in one of the four cycles of the ICT in IBSE course and the background information.*

<table>
<thead>
<tr>
<th>Participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
<th>Cycle 4 (N=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching subject</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>University</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VU</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>UU</td>
<td>7</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UvA</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TU-Delft</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>First-year teaching</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Partly paid/internship</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fresh master graduates</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

After the promotion of the course, most of the physics/chemistry student teachers in the four universities decided to enrol. The teacher educators estimated that about 20% of their student teachers did not enrol because they could not arrange free time in their school agenda and/or they already obtained enough credit points. Eventually, 40 Dutch student teachers participated in one of the four cycles of the ICT in IBSE course (Table 4.1). There is no
reason to suspect that this group of 40 student teachers is not representative for the population of student teachers of physics/chemistry in the Netherlands. Through an email to all of the 40 student teachers (also called course participants) and in the first live session as well, we explained the data-collection procedure for recording their activities in live sessions and their individual assignments and asked for their consent. All of them were willing to cooperate with us for the data collection.

4.1.3 Dutch participants and their teaching conditions

a) Characteristics of the Dutch participants

All 40 Dutch participants had, at least, a Bachelor of Science and one-year master studies in their subjects. They had research experience in their subject (e.g. thesis work) as well as certain experimentation/modelling skills for handling laboratory equipment and software (e.g. laboratory and ICT course). In addition, before the course, they had learned about IBSE in their teacher-education programmes.

The participants’ ages varied from 24 to 50 years, and only half of the participants were fresh master graduates (Table 4.1). The other half obtained their master degree many years ago, then worked for many years in a research or industrial job, and decided either by choice or through reorganizations to opt for teaching. As a result, the group of 40 Dutch participants (more physics than chemistry) was heterogeneous in terms of

- mastery of subject area knowledge: from just graduated (43%) to a PhD (10%) or post-master research experience (15%) in physics or chemistry;
- experience with the ICT tools: standard-deviation bars in Figure 4.1 reflect the participants’ heterogeneity in regard to their familiarity with the Coach tools before the course.

![Figure 4.1](image)

Figure 4.1. Level of Dutch participants’ familiarity with each Coach tool before the course (self-report via the pre-course questionnaire; 5-point scale, 1 = not at all familiar, 5 = extremely familiar).

No chemistry participants knew about video measurement. About one third of the 40 participants were quite familiar with data logging in science education through their work in
school. Eight participants had no experience with Coach, but with another platform. The number of participants, who knew about modelling before the course, increased slightly across the four cycles (Figure 4.1). This was probably an effect of recent integration of modelling in the Dutch school-science curriculum.

b) Teaching conditions of the Dutch participants

Dutch teachers have freedom in selecting topics, methods, equipment and software for the classroom activities. The Dutch Ministry of Education is not allowed to prescribe teaching methods and sequences. Furthermore, the Dutch curricula encourage teachers to teach the basic concepts in relation to situations familiar to pupils and through practical work or demonstrations with laboratory equipment and computer (Ellermeijer, Landheer, & Molenaar, 1996; Ellermeijer, 2004).

Teaching conditions in the participants’ practicum schools, however, were remarkably different. The Dutch participants taught at various levels: first or last years of HAVO (higher general secondary education) or VWO (pre-university). Many, but not all, had sufficient software, sensors, interfaces, computers for ICT-integrated lessons, but in some schools, these were rarely used. Via the follow-up questionnaire, we asked the participants to evaluate their teaching conditions for inquiry-based teaching and application of the ICT tools. The response data show that there were considerable differences among participants’ schools regarding different aspects (see standard-deviation bars in Figure 4.2).

![Figure 4.2](image)

8.1. Availability of computers, software, and sensors
8.2. Opportunities within the school curriculum
8.3. Pupils’ experience with inquiry based learning
8.4. Pupils’ experience in using ICT tools
8.5. Encouragement by the school management
8.6. Support from colleagues

Figure 4.2. The Dutch participants’ self-evaluations of their teaching conditions for application of ICT and IBSE in the classroom (N=22) (5-point scale, 1=poor, 5=excellent).

4.1.4 Time constraints as boundary conditions of the Dutch course

When analysing the Dutch context, we realised three aspects of the general time-constraint situation of the course. In particular, time was limited a) for live sessions, b) for participants to carry out individual assignments, and 3) for the ICT in IBSE try-out within the school curriculum.

a) Limited time for live sessions

Total study time allocated to the course was just 28 hours equivalent to one ECTS credit point. Within the 28-hour study time, 12 hours or four sessions at most could be allocated as contact time. This time was very limited, considering extensive activities
intended for live sessions such as demonstrations, hands-on practice with the ICT tools, preparation of the lesson plan, and discussions (see Chapter 3, Table 3.3).

b) Limited time for participants to carry out assignments in between live sessions

Of all 33 participants, 82% were in the first year of teaching; 18% had a few but less than five years of teaching experience (Table 4.1). In these novice and threshold phases of the teaching career, Dutch participants experienced tensions regarding transition of knowledge and skills gained from pre-service teacher education to fulfilling the professional demands. Meanwhile, 12 participants (36% of N=33) already had a teacher appointment (Table 4.1) rather than only a guided internship. Many participants reported that they were facing all pressures of first-years teaching with regular lessons and extra school duties. Simultaneously they struggled with managing time and energy needed to comply with the demands of their teacher education programme such as university-course assignments and school-based projects. This resulted in limited time for the Dutch participants to carry out individual assignments like those of the ICT in IBSE course.

c) Limited time within the curriculum for participants’ ICT in IBSE try-outs

In a short duration in between live sessions, it would be difficult to find relevant topics within the physics/chemistry curriculum for the ICT in IBSE lesson. Moreover, the time per week for physics or chemistry lessons was short (i.e. typically two 50-minute periods per week), whereas there were still many content-knowledge goals to attain. Here were two of many participants’ complaints about this curriculum constraint as a hindering factor for the ICT in IBSE try-out:

- “The curriculum is very filled up for students in class 4 and 5. This is why there is little time for extra ICT exercises.”
- “Academic knowledge is a big part of the curriculum and has priority over inquiry activities”.

In this dissertation, we use direct quotes from the participants’ opinions, which were stated in written forms in questionnaires or verbal forms in live discussions. A few quotes contained English grammar and/or spelling mistakes, so we corrected. Two members of the research team checked the English correction to ensure that the original meaning of the quote was unchanged.

4.1.5 Suitability of the pedagogical principles for the Dutch context

The pedagogical principles were operationalised in the initial scenario of the Dutch ICT in IBSE (see Chapter 3, Section 3.2) in consideration with the characteristics of the Dutch participants and time-constraint conditions of the Dutch course. In particular, the “one theory-practice cycle” principle matches with the Dutch participants’ potentials in designing and trying out the ICT in IBSE lesson within the course. This resulted from the considerations regarding a) their research experience and certain laboratory/ICT skills, b) their autonomy in the school and laboratory/ICT-enhanced curricula, c) pupils’ familiarity with inquiry practices, laboratory equipment, and computers. The “ownership of learning” principle matched well with the heterogeneity of the Dutch participants, concerning their background and teaching conditions. This principle allows their freedom to select what to learn and how to learn it using the course scenario and support materials to achieve the course objectives.
Additionally, the distributed-learning principle was relevant to time-constraint conditions of the Dutch course. Considering that the course in Cycle 1 of the Dutch context was limited to 5 weeks and 28 hours of total study time, in Chapter 3 we elaborated the initial scenario, including concrete programme for three live sessions and explicit requirements for two individual assignments (Table 3.2). Support materials, online support, and logistics for the course participants were already presented as well. For the distributed-learning principle to be implemented sufficiently,

- Regarding limited contact hours for live sessions, we had to select the most significant activities and the most appropriate timing;
- Regarding limited time that the participants could invest for assignments, we had to limit their assignments to the most essential;
- Regarding the curriculum constraint for the ICT in IBSE try-out, we had to define the most effective timeframe that balances between designing a good lesson plan and completing the try-out within the course.

However, what were the most significant activities and appropriate timing for live sessions? What were the most essential for assignments? What was the most effective timeframe for live sessions and assignments? We did not know the answers yet before the actual implementation of the course scenario in Cycle 1. After each iterative cycle of implementation and evaluation of the scenario, these issues became clearer.

4.2 Formative evaluation and optimisation of the Dutch ICT in IBSE course through the three cycles

4.2.1 About operationalization of the “one theory-practice cycle” principle

a) Methods

In the initial scenario, the participants were expected to fulfil the following stages of one theory-practice cycle at the following moments (Table 4.2):

- a) complete the Coach activity for the ICT in IBSE lesson plan within Session 2,
- b) complete the lesson plan (incl. the Coach activity and the learning scenario) between Sessions 2 and 3,
- c) complete the classroom try-out of the lesson plan before Session 3,
- d) complete the self-evaluation report of the classroom try-out before Session 3.

In order to evaluate and discuss the operationalization of the “one theory-practice cycle” principle, we evaluated whether or not the participant can complete each stage of one theory-practice cycle at the intended moment. Based on participants’ assignment reports and the observation of Sessions 2 and 3, we recorded when each participant finalised each of these four stages and compared the record to the intended moment. Moreover, to understand possible obstacles for carrying out the complete cycle, we would question participants in Sessions 2 and 3, via email, and/or after the try-out.

b) Results

In Cycle 1, before Session 3, 7 participants (out of N=12) had just finished their lesson plans (incl. the Coach activity), and only 2 participants had tried out their lesson plans (Table 4.2). Accordingly, the intended activities for Session 3 had to be adjusted to suit
participants at different stages of one theory-practice cycle. Unintentionally, the 10 participants who did not try out yet had to spend time in the weeks after the course to complete it. Eventually, 9 out of these 10 participants managed to implement their ICT in IBSE lessons, but they did not have an opportunity to get feedback on their try-out, which was intended for Session 3.

Table 4.2. Number of the Dutch participants in each cycle, who completed each stage of one theory-practice cycle.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) completing the Coach activity</td>
<td>12</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>• within Session 2*</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>• between Sessions 2 &amp; 3</td>
<td>7</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>b) completing the lesson plan</td>
<td>12</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>• within Session 2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>• between Sessions 2 &amp; 3*</td>
<td>7</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>c) completing the classroom try-out</td>
<td>11</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>• before Session 3*</td>
<td>2</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>9</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>d) completing the self-evaluation report</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>• before Session 3*</td>
<td>1</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

(*) The marks “*” indicate at which moment each stage was expected to be completed by all participants.

The email history showed that one Cycle-1 and three Cycle-2 participants did not submit their lesson plan to the course instructor before their try-outs as expected (to get feedback for improvement). Of 11 Cycle-1 and 7 Cycle-2 participants who managed to submit the lesson plan in advance, 3 Cycle-1 and 2 Cycle-2 participants just sent it in the evening before the try-out. In the Session-3 discussion, the Cycle-1 participants complained that the course was too short. An example of such complaint is the following:

“The course was useful, but the five week duration with three meetings was too short to get myself equipped with the Coach environment and also give an IBSE lesson using Coach. I would recommend that the course for next year should be spread over a longer duration, so then participants have enough time to reap its full benefit.”

According the participants, this short duration did not allow them to find sufficient time for assignments due to their demanding workload. The demanding workload was related to high cognitive load as reflected in the following feedback of a participant:

“I’m overworked and overstressed as I’ve been pretty much thrown in the deep end at school with very little guidance or supervision due in part to the unfortunate timing of developments related to my SPD and events at school…I find it very frustrating to see how much can be done with a tool such as Coach, but how little in practice I can achieve given the circumstances (lack of means, guidance and momentum at school).”
The Cycle-1 and Cycle-2 participants also reported that finding possibilities for the ICT in IBSE try-outs in between Sessions 2 and 3 (i.e. 3-4 weeks) was difficult. Following were three particular obstacles involved:

First, limited room in the school physics or chemistry curricula for an ICT in IBSE lesson (see also Section 4.1.4). For instance, a participant could not find any opportunity to integrate modelling activities in the subject of direct current circuits, which she would teach in the weeks between Sessions 2 and 3. In another case, four participants found a topic within the curriculum for the try-out. However, these participants had to teach a few other lessons beforehand to prepare their pupils with the prerequisite knowledge. Consequently, the try-out was not arranged before Session 3.

Second, a strong impact of the school’s agendas, especially at the end of the school year as in Cycle 2. There were many holidays; the participants rushed to complete all lessons and prepare pupils for the final exam as illustrated by the following report:

“I have to come to an agreement with the teacher of the class I run as an intern. The class is not yet familiar with Coach, so the teacher is afraid that too much time will be consumed while the regular teaching programme for this year is slightly behind schedule.”

Consequently, they had great trouble finding opportunities for the try-out. Four Cycle-2 participants had to find opportunities for the try-out in the subsequent school year. Eventually, two participants (out of 4) could try out their ICT in IBSE lesson, whereas the two others could not make it because the unfinished assignment interfered with their new tasks.

Third, lack of ICT facilities. For instance, three Cycle-1 participants and two Cycle-2 participants reported that their schools lacked Windows PCs, Coach interfaces, and sensors. These facilities were needed for the ICT in IBSE topics, which they chose in Session 2. It took time for them to find alternatives for the classroom try-out after Session 2. For one of them, the lack of the ICT equipment in the school was the main reason for not trying out his lesson plan at all.

One participant even had to cancel the course because he could not find any opportunity for the classroom try-out. Here is part of his cancellation email:

“I would like to cancel my participation due to my current workload. Another reason is that the remainder of the course is aimed at preparing and developing an ICT in IBSE lesson plan and trying it out in school before March 4th. Unfortunately, this course objective is not feasible for me at this stage” (This student teacher cancelled participation in Cycle 1, but took part and completed the course in Cycle 2.)

c) Discussion and revisions of the course

Operationalization of the “one theory-practice cycle” principle was not implemented faithfully in Cycle 1, considering that many participants could not complete the four stages of one theory-practice cycle at the intended moments during the course (Table 4.2). The high workload and the lack of ICT facilities were situations that we could not change. However, we could revise the timeframe and requirements of the assignments and support participants better in finding possibilities and designing the lesson plan for the classroom try-out.
About the timeframe. Although the course was limited by the 28-hour total study time, it was possible within a semester to spread out the duration between the first and last sessions. Therefore, we allocated one more week for each assignment for Cycle 2. This timeframe in Cycle 2 was not yet long enough as there were still 5 participants (out of 12) who could not complete the try-out before Session 3 and 2 participants who did not fulfil the try-out at all (Table 4.2). Therefore, we allocated 11 weeks for the course for Cycle 3, in which the time between Sessions 2 and 3 was extended considerably (i.e. 9 weeks).

About requirements of the assignments. There were no Cycle-1 participants and only two Cycle-2 participants (Table 4.2) completing the Coach activity within Session 2 as expected. It took the participants considerable time in between Sessions 2 and 3 to finalise the lesson plan, whereas they still had to try out the lesson in such limited duration. In conclusion, it was unrealistic to expect that the participants could start preparing the Coach activity during the second half of Session 2 and complete it within the session (Table 4.2). The participants needed sufficient time to think about the topic; modify or design the Coach activity; and troubleshot arising problems. Therefore, we revised the requirements of each assignment for Cycle 3 as follows:

- Assignment 1 started after Session 1 and had to be completed before Session 2, including two parts:
  - Part a for learning manipulation skills (as in Cycles 1 and 2)
  - Part b for preparing a draft of the Coach activity and the learning scenario for the ICT in IBSE lesson plan (new component).
- Assignment 2 started after Session 2 for trying out the ICT in IBSE lesson and had to be completed before Session 3.

This would stimulate the Cycle-3 participants to find opportunities for the ICT in IBSE try-outs earlier, so perhaps more possibilities would appear. Additionally, the Cycle-3 participants would get direct support of the course instructor to troubleshoot problems with the Coach activity and improve the learning scenario of the ICT in IBSE lesson. Therefore, they would finalise the lesson plan soon after Session 2.

Did the revisions work out? In Cycle 3, all participants completed one theory-practice cycle; 7 participants (out of 9) tried out and self-evaluated their lesson plans before Session 3 as expected (Table 4.2). Especially, a participant completed two ICT in IBSE try-outs, and then submitted the one, which he was more satisfied with pupils’ engagement. Concerning the new part of Assignment 1, 7 participants (out of 9) managed to prepare the draft of the ICT in IBSE lesson plan before Session 2. After that, 4 participants completed the lesson plan within Session 2, and 3 others completed it soon enough for the try-out before Session 3. Importantly, the fulfilment of one theory-practice cycle resulted in intensive discussions about ICT in IBSE try-outs in Session 3. Here was the course instructor’s evaluation about these discussions:

“I had been worried about whether the discussions about the try-out would be intensive enough and whether the student teachers would become clear about what they were learning. However, it all worked out well. It was nice to see what the student teachers have done with Coach and that they are sensitive to the teaching aspects of using Coach. The presentations focused on the pedagogy of using Coach in IBSE, not on technical difficulties, and these were good discussions.”
These results proved positive effects of the revisions regarding the timeframe and the assignment requirements in Cycle 3.

**d) Conclusions about operationalization of the “one theory-practice cycle” principle**

The above results of the formative evaluation regarding the “one theory-practice cycle” principle show that operationalization of this principle was implemented faithfully in Cycle 3. The cyclic refinement of the course led us to the conclusion about the following practical conditions for this principle to be implemented faithfully:

- sufficient duration anticipated for the classroom try-out (i.e. 9 weeks between Sessions 2 and 3),
- the start of designing the lesson plan right after Session 1.

### 4.2.2 About operationalization of the distributed-learning principle

In order to evaluate and discuss the operationalization of the distributed-learning principle, we evaluated the following aspects:

- Were available time and format of live activities sufficient for participants?
- Was the online support helpful for participants’ learning outside live sessions?
- Did the participants spend sufficient time outside live sessions?
- Did the participants appreciate the distributed learning scenario?

In this section, we describe these evaluations and discuss how we revised the course toward more faithful implementation of the distributed-learning scenario in Cycle 3.

**a) Were available time and format of live activities sufficient for participants?**

**Methods.** We observed live activities (Table 4.3), took notes about how long each activity actually took, and compared the data to the intended time in the programme. Moreover, we asked the participants the following question via the post-course questionnaire:

> “suppose the total time for our ICT in IBSE course is unchanged, how would you prefer to change the time consumed for each activity in each live session of the course?” (3-point scale, -1=less time, 0=unchanged, 1=more time). Next, based on participants’ responses, we computed the weighted average that reflects to what extent the group of participants in each cycle desired more or less time for each activity (Table 4.3). For all live activities, we calculated the mean and the standard deviation that reflect the participants’ general satisfaction about the timing of the live sessions in each cycle. These values for the three cycles are visualised in Figure 4.3. Furthermore, in Session 3 we asked the participants to evaluate the live activities and suggest refinements of these activities for the sequential cycle.

**Results.** In Cycle 1, plenary presentations and discussions within Sessions 1 and 2 lasted longer than intended, so the individual and group activities were shortened considerably. According to the Cycle-1 participants’ responses to the post-course questionnaire, they preferred individual practice and group interactions to plenary, so desired more time for such individual and group activities (Table 4.3). Table 4.3 and Figure 4.3 (i.e. the standard-deviation bar of the first column) show that in general Cycle-1 participants were not content with the timing of live activities.
Table 4.3. Intended and actual timing of live activities in Cycle 1 and Dutch participants’ suggestions for changes of the time consumed for each live activity. The Cycle-1 participants (N=12) suggested through the 3-point scale question (-1=less time, 0=unchanged, 1=more time).

<table>
<thead>
<tr>
<th>Live activities of participants</th>
<th>Format</th>
<th>Intended (minutes)</th>
<th>Actual (minutes)</th>
<th>Participants’ suggestions (weighted average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1. Listening to the introduction of the ICT tools</td>
<td>Plenary</td>
<td>45</td>
<td>55</td>
<td>Less time (- 0.2)</td>
</tr>
<tr>
<td>Section 1. Practising manipulation skills through the Coach activities</td>
<td>Group of two or individual</td>
<td>90</td>
<td>70</td>
<td>More time (+ 0.5)</td>
</tr>
<tr>
<td>Section 2. Discussing problems related to Assignment 1</td>
<td>Plenary</td>
<td>40</td>
<td>50</td>
<td>Less time (- 0.5)</td>
</tr>
<tr>
<td>Section 2. Listening to the instruction about IBSE</td>
<td>Plenary</td>
<td>50</td>
<td>55</td>
<td>Less time (- 0.2)</td>
</tr>
<tr>
<td>Section 2. Preparing the Coach activity for the lesson plan</td>
<td>Individual</td>
<td>90</td>
<td>60</td>
<td>More time (+ 0.6)</td>
</tr>
<tr>
<td>Section 3. Reporting and evaluating the try-outs</td>
<td>Plenary</td>
<td>100</td>
<td>70</td>
<td>Less time (- 0.5)</td>
</tr>
<tr>
<td>Section 3. Discussing added value of the ICT tools</td>
<td>Plenary</td>
<td>15</td>
<td>25</td>
<td>Less time (- 0.5)</td>
</tr>
</tbody>
</table>

Figure 4.3. The Dutch participants’ generalised suggestion to change the timing of live activities in each cycle; the standard deviations reflect differences among suggestions per activity (not per participant), and these deviations decreases across the three cycles.

In the Section-3 discussion, the Cycle-1 participants indicated that plenary activities were generally too lengthy. In particular, part of the plenary discussion about ICT manipulations concerning Assignment 2 (Table 4.3) was not related to their individual assignments. For example, manipulation problems regarding Coach video measurement shared with the whole class were not directly useful for the group of participants who specialised in Coach modelling or data logging. Furthermore, the Cycle-1 participants desired detailed feedback on their assignment reports in Sessions 2 and 3 (Table 4.3) rather than few comments in the plenary discussions due to the limited time. About the IBSE instruction, the participants would like to be engaged more in the discussion about IBSE (Session 2) rather than mostly listening and asking questions if necessary.
Discussion and revisions of the course. In Cycle 1, there was insufficient time for individual and group activities, and there was insufficient of minds-on discussion on IBSE. Such activities and discussion could have contributed to participants’ fulfilment of the two assignments. Thus, for Cycle 2 we revised the format of live activities as follows:

- **Session 2.** Manipulation problems with the ICT tool were discussed in the group of participants who practiced the same tool.
- **Session 2.** The focus of the instruction about inquiry-based teaching was shifted to an exercise on how to change a prescriptive laboratory activity to become more inquiry. The prescriptive instruction is embedded in one of the Coach exemplary activities (see Chapter 3, Figure 3.5). A worksheet as new support material was developed for the IBSE exercise (see Appendix E), including the following discussion questions:
  - Which minds-on items (thinking back-and-forth between experiment and theory) are already in the instructions?
  - How could you make the experiment more minds-on yet; think especially about what could be done before the experimental procedure.
  - How could you make the experiment more IBSE?
  This discussion, therefore, illustrated how to modify the Coach exemplary activities for the ICT in IBSE try-out.
- **Session 3.** The participants reported their ICT in IBSE try-outs in the group of participants who taught the same subject and/or applied the same ICT tool.

Did the revisions work out? In the Session-3 discussion (Cycles 2 & 3), there was no suggestion of participants about changing the format of the live activities. Figure 4.3 shows that in general, Cycle-2 and Cycle-3 participants were more satisfied with the timing for live activities than those in Cycle 1 (the standard-deviation bars are shorter).

b) Was the online support helpful for participants’ learning outside live sessions?

Methods. We reviewed the Moodle and email log to examine whether or not the participants made use of the online platform and online consultation. In addition, we asked the following questions to the participants via the post-course questionnaire:

- “From your working experience with the online platform, please indicate its advantages and disadvantages” (Open ended)
- “To what extent are instructions from the course instructor through the online consultation useful to you in learning to use and apply the ICT tools?” To respond, the participant clicked on a 5-point scale (1 = not at all useful, 5 = extremely useful) or selected the option: “I did not use it, so I have no idea”.

Moreover, to understand possible obstacles in consulting the course instructor via the Internet, we would question the participant after the classroom try-out.

Results. The Moodle log showed that all participants in Cycles 1 and 2 logged on and downloaded support materials. However, no participants used the Moodle forum, which was intended as main means of consultation in Cycles 1 and 2. The participants’ feedback to the open-ended question indicated that the online platform included useful support materials and valuable links to the ICT in IBSE examples. However, 15 out of 22 respondents in Cycles 1
and 2 reported their struggle with technical details of Moodle with regard to creating an account, finding information, and uploading files to the Moodle forum.

Of 32 respondents (out of total 33 participants) to the Likert question, 56% consulted the course instructor via email about their problems in learning to use and apply the ICT tools (Table 4.4). Of these consulted problems, the email log recorded nine particular troubles (4 in Cycle 1, 3 in Cycle 2, 2 in Cycle 3) of seven participants; these troubles were related to the Coach activity for the lesson plan. To support the participants to tackle these troubles, the course instructor made descriptive texts with screen-shoots and/or video clips and sent these instructions via email. Using these instructions, the participants then could troubleshoot their problems and keep progressing in learning the ICT tool and preparing their lesson plan. Participants who used this email consultation evaluated it as moderately useful for them (Table 4.4).

Table 4.4. Number of the Dutch participants who used the online consultation and their evaluation on its usefulness (5-point scale, 1 = not at all useful, 5 = extremely useful).

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants using the online consultation</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Participants’ evaluation on usefulness of the online consultation - Weighted average (SD)</td>
<td>3.9 (0.1)</td>
<td>3.5 (0.5)</td>
<td>4.2 (0.4)</td>
</tr>
</tbody>
</table>

According to the discussion after the classroom try-out, the participants actually took much time to explain their problems of the Coach activity, and then discuss back and forth via email. There were other participants, who also faced difficulties with the Coach activity, but they asked their colleagues in the school and/or left the problems for live sessions. The email log recorded that of all participants, 61% (8 out of 12 in Cycle 1, 5 out of 12 in Cycle 2, 7 out of 9 in Cycle 3) managed to complete their lesson plan and consulted the course instructor via email for improvement before the try-out. According to these participants, feedback of the course instructor was very helpful for them to fine-tune the learning scenario for the lesson plan and to implement the classroom try-out.

**Discussion and revisions of the course.** Considering the feedback about disadvantages of the Moodle environment in Cycle 1, we revised the structure and text in the Moodle platform and forum. However, the Cycle-2 participants did not use the Moodle forum for online consultation either. Therefore, to eliminate unnecessary frustrations with the Moodle environment, in Cycle 3 we used a static, simple webpage as the course’s online platform (Figure 4.4). The Cycle-3 participants submitted assignment reports and consulted for their problems via email.

In Cycles 1 and 2, the email consultation was helpful for the participants in refining the learning scenario and troubleshooting problems of the Coach activity for the lesson plan. However, it was time consuming. Meanwhile, the participants could only invest 2 to 5 hours for the assignment (Table 4.5). In Cycle 3, the participants had more opportunities in Session 2 to consult each other and the course instructor about their problems in modifying or developing the Coach activity (see Sections 4.2.1). Consequently, there would be less demand
for troubleshooting support outside live sessions via the email consultation. However, it does not mean that the email consultation was less beneficial in Cycle 3. Of 8 respondents (out of 9 Cycle-3 participants), 5 participants (63%) made use of the email consultation and evaluated it as very useful for them (4.2 of the 5-point scale) (Table 4.4).

**Pre-service course: Integration of ICT into IBSE**

**Venue:** Foundation CMA, A.J. Ernstraat 169, 1083 GT Amsterdam

**Introduction**

The course aims at effective pre-service teacher learning to use and apply the Coach tools (data logging or video measurement or modeling) in inquiry-based physics/chemistry lessons in the secondary school. The student teachers are expected to:

- Become aware of possibilities of all three Coach tools, but study in depth only one tool by choice;
- Try out classroom activities through a complete cycle of designing, implementing, and evaluating one ICT-integrated inquiry-based lesson.

The participants are strongly encouraged to study on their own most of the time through preparing themselves before the first meeting and carrying out the two tasks in between the sessions with support materials. The program for three life sessions, description of in-between tasks are sent to the course participants via individual mails.

**Support materials**

Most of the support materials are grouped by theme in *.rar files. If your computer has not have WinRAR installed yet, please install it to extract the zipped materials.

**Background materials**

Background materials include introductory PowerPoint presentations about the Coach tools and articles on the use of these tools in science education in the Netherlands.

Click to download the PowerPoint presentations and background articles.

**Coach activities**

To learn using a particular tool, participants are advised to practise the given Coach activities which are categorized into three levels:

![Image](http://www.cma-science.nl/ICTcourse/index.html)

User name: ICT and password: cmaict2015 are required to access the website.

**Figure 4.4.** Website of the Dutch ICT in IBSE course for Cycle 3, including course description and support materials (http://www.cma-science.nl/ICTcourse/index.html). User name: ICT and password: cmaict2015 are required to access the website.

**c) Did the participants spend sufficient time outside live sessions?**

**Methods.** In Session 1, we asked the participants to estimate how much time they actually spent for preparing themselves before the course. In the assignment reports, the participants had to estimate how much time was spent for a) practising the ICT tool, b) designing the lesson plan, c) trying out and evaluating the lesson. Based on these estimates, we calculated the average time for each activity and summed the actual time for all activities outside live sessions. Then we compared the actual time with the time anticipated for learning outside live sessions.

**Results.** Table 4.5 shows that in Cycles 1 and 2, the participants spent considerably less time for learning outside live sessions than anticipated. In Cycle 3, the participants invested slightly more time outside live sessions than intended (17.1 actual hours and 16 anticipated hours). The most time-consuming task of Cycle-3 participants outside live sessions was designing the lesson plan (7 hours, SD = 3.6). This was followed by 3.8 hours (SD = 2.4) for acquiring manipulation skills with the ICT tool and 3.5 hours (SD = 1.4) for the classroom try-out.

**Discussion.** In Cycle 3, the participants did spend sufficient time for learning outside live sessions; while they were under the demanding workload. Designing the lesson plan (incl. the Coach activity and the learning scenario) proved to be the most essential activity outside live sessions, considering the fact it required the most time of participants.
Table 4.5. Intended time frames for the learning scenario in different cycles of the Dutch ICT in IBSE course and average time spent for learning outside live sessions.

<table>
<thead>
<tr>
<th>Time frame</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration in total</td>
<td>5 weeks</td>
<td>7 weeks</td>
<td>11 weeks</td>
</tr>
<tr>
<td>• Duration for Assignment 1 (weeks)</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>• Duration for Assignment 2 (weeks)</td>
<td>3</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Total study time</td>
<td>28 hours</td>
<td>28 hours</td>
<td>28 hours</td>
</tr>
<tr>
<td>• Time allocated for 3 live sessions (hours)</td>
<td>9</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>• Time anticipated for learning outside live sessions</td>
<td>19</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Average time actually spent* outside live sessions</td>
<td>13.8 hours</td>
<td>12.9 hours</td>
<td>17.1 hours</td>
</tr>
<tr>
<td>• Preparing before the course (SD) (hours)</td>
<td>2.3 (0.9)</td>
<td>2.2 (1.1)</td>
<td>2.8 (1.4)</td>
</tr>
<tr>
<td>• Practising the ICT tool (SD) (hours)</td>
<td>3.6 (1.4)</td>
<td>4.2 (2.1)</td>
<td>3.8 (2.4)</td>
</tr>
<tr>
<td>• Designing the lesson plan (SD) (hours)</td>
<td>5.1 (1.9)</td>
<td>3.9 (2.5)</td>
<td>7.0 (3.6)</td>
</tr>
<tr>
<td>• Trying out and evaluating the lesson (SD) (hours)</td>
<td>2.8 (2.1)</td>
<td>2.6 (1.0)</td>
<td>3.5 (1.4)</td>
</tr>
</tbody>
</table>

d) Did the participants appreciate the distributed learning scenario?

**Methods.** We gathered the participants’ viewpoints about the course’s distributed scenario via the following open-ended question: "we distributed the three sessions over several weeks and included major assignments between these sessions [distributed scenario], instead of an intensive training during three consecutive days without assignments outside the course [massed scenario]. Which scenario do you prefer?" After that, we analysed each participant’s response and classified if the participant preferred the distributed scenario or the massed scenario. In case that the participants did not provide a clear point of view about their preference, we classified their feedback as neutral.

**Results.** Of all participants (N=33), 28 participants (85%) reacted to this open-ended question. Of all respondents, 67% in Cycle-1 (8 out of 12), 89% in Cycle 2 (8 out of 9), and 71% in Cycle 3 (5 out of 7) preferred the distributed scenario of the course to the massed setting (Table 4.6). Here is one of 21 participants’ supportive feedback:

"I prefer spread out sessions with tasks in-between. That gives me more time and occasions to practise the tool in a more realistic setting (that means doing what I really want to do with it without constant guidance). I get more time to think about what I really want to do and what kind of problems I really have and why. Then I can ask for appropriate help. With intensive training I always feel I'm doing what I'm told to do instead of what I will in actual fact want or need to do. The likelihood that I will afterwards actually use it is then much lower".

Table 4.6. Number of Dutch participants who preferred the distributed scenario, who preferred massed scenario, and who did not provide a clear opinion about their preference via the open-ended question.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
<th>Total (N=33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>• Preferring the distributed scenario</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>• Neutral</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>• Preferring the massed scenario</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Of all respondents, 5 participants (18%) had no preference and 2 participants (7%) preferred the massed set-up (Table 4.6). A disadvantage of the course’s distributed scenario was pointed out by a Cycle-3 participant as follows:
“To learn the possibilities of Coach itself I prefer an intensive training. To include a task with one of your classes, a setting over a longer period is preferable. It gives you the possibility to get feedback from your colleagues. A disadvantage of a longer period is the problem to keep your focus on course. When it takes several weeks before the next meeting, it is easy to lose your focus.”

Discussion. Already in Cycle 1, most participants appreciated the distributed scenario of the course, and the appreciation showed up in Cycles 2 and 3 as well. It was in the sense that the distributed learning enabled the participants’ ownership of learning, the classroom try-out of new knowledge, and reflection on such classroom experience. Keeping the participants on task proved to be crucial for the distributed learning, considering the fact that the participants faced distractions and obstacles when learning outside live sessions.

e) Conclusions about operationalization of the distributed-learning principle

The above results of the formative evaluation regarding the distributed-learning principle show that operationalization of this principle was implemented faithfully in Cycle 3 regarding:

- the relevant formats of live activities;
- the sufficient time that the participants spent outside live sessions;
- most participants appreciating the distributed scenario of the course;
- most participants making use of email consultation and evaluating it as very useful;
- the considerable number of participants who could complete the assignments at the intended time (see Section 4.2.1).

The cyclic refinement of the course led us to the conclusion about the following practical conditions for this principle to be implemented faithfully:

- the focus on the individual and group work that directly contributed to the lesson plan;
- the course website with support materials and the email communication for consultation and coordination (e.g. assignment reminder) that kept the participants on task while learning outside live sessions.

4.2.3 About operationalization of the depth-first principle

In order to evaluate and discuss the operationalization of the depth-first principle, we evaluated the following aspects:

a) Did the participants follow the one-tool specialisation?

b) Could the participants learn the ICT tool in depth?

c) After learning one tool in depth, were the participants confident to learn other tools by themselves?

In this section, we describe these evaluations and discuss how we revised the course toward more faithful implementation of the one-tool specialisation in Cycle 3.

a) Did the participants follow the one-tool specialisation?

Methods. For each participant, we recorded which tool was chosen in Session 1 (via observation of the session), which tool was practiced in Assignment 1, which tool was used for the ICT in IBSE lesson (via the assignment reports). After that, we checked whether the individual participant chose only one tool to learn and apply or not. To understand why the
individual participants did possibly not specialise in only one tool, we questioned them at the end of live sessions or via email.

**Results.** In Cycle 1, 11 out of 12 participants (92%) did not specialise in only one tool (Table 4.7). In Session 1, seven Cycle-1 participants practiced with more than one ICT tool after studying possibilities of these tools. Of 12 participants in Cycle 2, 7 participants (58%) did not follow the one-tool specialisation either (Table 4.7). In addition, 5 Cycle-1 participants (42% of N=12) and 4 Cycle-2 participants (33% of N=12) learnt to manipulate one tool and tried out the ICT in IBSE lesson with another tool.

*Table 4.7.* Number of Dutch participants who specialised in only one tool, who learnt two tools, and who learnt all three tools within the course.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialising in only one tool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Data logging</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>• Video measurement</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>• Modelling</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Learning two tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Data logging &amp; Video measurement*</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>• Data logging &amp; Modelling*</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Video measurement &amp; Modelling*</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Learning all three tools</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| (*)& The order of two tools does not reflect which tool was learnt first and second.

Regarding why many Cycle-1 participants learnt more than one tool in Session 1, we asked four Cycle-1 participants at the end this session and got the explanation that they were eager to explore possibilities of the tools, and they did not notice the requirement of focusing on only one tool. Regarding why many participants did not apply for the ICT in IBSE try-out the tool that they already learnt via Session 1 and Assignment 1, we questioned eight participants in Session 3 or via email. It turned out that the tool they chose to practice at the beginning of the course did not fit in their teaching conditions (e.g. pupils' familiarity with the tool, opportunities in the curriculum, availability of the ICT tool). They just recognised this when they started thinking about the ICT in IBSE lesson. Here was a particular case:

When choosing the video-measurement tool in Session 1, a participant thought that video measurement would be most interesting as her pupils could capture a video with their mobile phone. When preparing the Coach activity about a wave model for the try-out, she recognised the need of a high-speed camera, which the school did not have. Moreover, she realised that her 4 HAVO pupils seemed to have given up learning physics altogether, and so might not cooperate in the activity. Therefore, she explored alternatives with her colleagues for VWO classes because interpretation of measurements and modelling was a compulsory topic for VWO, and VWO pupils were somewhat more motivated. A colleague encouraged her Coach try-out with modelling because his 6 VWO class had not learnt modelling yet whereas it was part of the coming final exam. Eventually, she decided upon a modelling lesson for the 6 VWO class, and so she had to learn Coach modelling on her own to prepare for the lesson.

**Discussion and revisions of the course.** In Cycle 1, apparently we did not succeed in making the participants aware of the suggestion of one-tool specialisation. For Cycle 2, we revised the course description to highlight the purpose of mastering only one tool. During Session 1, we emphasised the importance of the one-tool specialisation for participants to
achieve the mastery that would enable them to design and teach the ICT in IBSE lesson. As a result, only two Cycle-2 participants practiced more than one tool in Session 1. Furthermore, when choosing the ICT tool to specialise in, many Cycle-1 and Cycle-2 participants were not sure if that tool would fit their teaching conditions for the try-out. Therefore, for Cycle 3 we raised the issue of choosing one out of three ICT tools for the classroom try-out as part of the pre-course preparation. In particular, the participants had to read the introductory slides to get to know all three tools and consult the teacher mentor about which Coach tool would

- match with their school conditions (e.g. availability of software, hardware, and computer; pupils’ experience with the ICT tool)
- be applicable within the physics/chemistry curriculum intended between Sessions 2 and 3.

**Did the revisions work out?** Effects of these revisions showed up in Cycle 3 as all participants practiced only one tool in Session 1, and 7 out of 9 participants (78%) did learn and apply only one tool by their own choice (Table 4.7). Evidently, bringing to the front the choice of which ICT tool to try out in the school (i.e. before the course) helped the Cycle-3 participants to make this choice better and earlier than those in Cycles 1, 2.

*b) Could the participants learn the ICT tool in depth?*

**Methods.** In order to evaluate if the participants could learn the ICT tool in depth, we analysed if they achieved the mastery that would enable them to design a new Coach activity or at least modify the given Coach activities. Based on the submitted lesson plan including the Coach activity, we examined if the Coach activity was selected or modified from the given one or totally new. To understand possible difficulties for the participants in learning the ICT tool, we recorded:

- questions of participants to the course instructor when they practiced with the ICT tool in Session 1,
- difficulties described in the assignment report on practice with the ICT tool (Assignment 1),
- discussions on problems regarding manipulations of the ICT tool at the beginning of Session 2,
- questions via email about problems of the Coach activity for the ICT in IBSE lesson plan.

After the classroom try-out, we questioned the participants about their difficulties in preparing the Coach activity for the ICT in IBSE lesson plan. To evaluate the effects of live instructions about the ICT tool, we asked the participants the following question via the post-course questionnaire: “to what extent are instructions from the course instructor in live sessions useful to you in learning to use and apply the ICT tools?” (5-point scale, 1 = not at all useful, 5 = extremely useful).

**Results.** Table 4.8 shows that almost all participants could prepare the Coach activity for the lesson plan. Furthermore, we see a shift from the dominant use of given Coach activities without modification in Cycle 1 to the dominant use of the new Coach activities in Cycle 3.
Table 4.8. Number of Coach activities (of the Dutch participants) which were selected or modified from the Coach library or totally new.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Coach activities selected/modified/developed for the ICT in IBSE lesson plan</td>
<td>11*</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>• Coach activities selected from the Coach library</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>• Coach activities modified from the Coach library</td>
<td>3</td>
<td>6</td>
<td>3**</td>
</tr>
<tr>
<td>• New Coach activities***</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

(*) Each participant designed one Coach activity for the classroom try-out, except for only one case where two Cycle-1 participants designed and tried out one lesson together.

(**) Two Cycle-3 participant modified Coach modelling activities, which were given in CD attached with physics textbooks. We considered these activities as from the Coach library.

(*** Brief descriptions of the newly developed Coach activities:

<table>
<thead>
<tr>
<th>Cycle 1</th>
<th>1. Chemical equilibrium</th>
<th>Modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Determining the shape of an object</td>
<td>Data logging</td>
<td></td>
</tr>
</tbody>
</table>

| Cycle 2 | 3. Temperature dependence of a resistance | Data logging |

<table>
<thead>
<tr>
<th>Cycle 3</th>
<th>4. pH calculation after dissolving HCl</th>
<th>Modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Horizontally-launched projectile</td>
<td>Video measurement</td>
<td></td>
</tr>
<tr>
<td>6. Resonance of a wine glass</td>
<td>Data logging</td>
<td></td>
</tr>
<tr>
<td>7. Felix Baumgartner's supersonic fall from space</td>
<td>Modelling with real data</td>
<td></td>
</tr>
<tr>
<td>8. Objects moving on an inclined plane</td>
<td>Modelling</td>
<td></td>
</tr>
</tbody>
</table>

With regard to difficulties in learning the ICT tool, individual participants asked questions about common features of the Coach software environment (e.g. analysing and processing data). They also asked about particular concepts (e.g. modelling: state variables, auxiliary variables, flows, constants, events) and technical manipulations (e.g. modelling: how to connect variables and constants). There were more questions about Coach modelling than about video measurement or data logging. The course instructor reacted to the participants quickly, and then the individual participants got over these initial frustrations and kept learning the ICT tool. Additionally, we observed participants’ problems beyond basic manipulation skills. An example:

In Session 1, a participant practiced the Coach tutorial activity about measuring coordinates of a pendulum bob over time and then plotting the graph of the horizontal coordinate (x) vs. time. He predicted from theory that the y-t graph would have the sine shape as the x-t graph. Therefore, he also plotted the y-t graph to check his prediction although this was not required in the text instruction. The y-t graph turned out to be unexpected (Figure 4.5), whereas the x-t graph resembled a theoretical sine shape. He repeated the measurement several times, clicking on the centre of the bob as precisely as he could, but the result did not look better. He struggled with this problem for almost the entire hands-on time. Eventually, he asked for help. The course instructor explained to him that errors in the measurement of x, y coordinates could not be avoided due to the actual set-up and manipulations (e.g. spatial perspective, scaling, and inconsistent clicking on the centre). Change of x (about 30 cm) was much larger than the error (about 1 cm), so the error was not seen clearly on the x-t graph. Meanwhile, change of y was only about 4 cm, so the error was not negligible, and it was obvious in the y-t graph (Figure 4.5).
Figure 4.5. Screenshot of a Coach activity for measuring on a video of a pendulum with x vs. t above and y vs. t below.

The participant, in this case, did not have any difficulties regarding manipulations of the tool but problems regarding the physics issue of how to interpret the experimental data. He took too much time being stuck in this problem. With the instructor’s help in a few minutes, he got the point quickly.

Via the assignment report and the discussion in Session 2, the participants reported that they could follow the text instructions and did learn manipulation skills through the given Coach activities. Additionally, each participant reported one or two problem(s) that she or he could not solve yet. These problems appeared when they tried to recreate the activity from scratch and/or tried things apart from the text instruction. These problems were then solved quickly with help of the course instructor and/or fellow participants in Session 2. Via the email consultation, we also recorded participants’ problems regarding the Coach activity for the lesson plan (see Section 4.2.2). Via the discussion after the classroom try-out, we learnt from three participants (two in Cycle 1 and one in Cycle 3) that they first had interesting ideas for the ICT in IBSE lesson, but when developing the new Coach activity, they encountered difficulties, tried to troubleshoot, but failed. However, they did not consult the course instructor due to lack of time. Eventually, they opted for choosing an existing Coach activity and modifying it.

Discussion and revisions of the course. Developing a new Coach activity demanded from participants a good idea, a feasible design of the activity, sufficient skills with Coach, and some experience with troubleshooting. In Cycles 1 and 2, the participants did not achieve a satisfactory level of mastery with the ICT tool as only two Cycle-1 and one Cycle-2 participants could develop new Coach activities. This does not mean that the quality of live instructions about the ICT tool was poor. The Cycle-1 and Cycle-2 participants’ responses to the Likert question asserted that instructions from the course instructor in live sessions were very useful for them in learning to use and apply the ICT tools (3.9 - 4.3 of the 5-point scale).

In fact, when learning the ICT tool in depth, the participants faced initial hurdles regarding new concepts and manipulation skills and later on problems of the Coach activities for the lesson plan. Three hours for Session 1 (Cycles 1 and 2) were not sufficient in
preparing the participants to learn and apply the ICT tool on their own. Therefore, for Cycle 3 we extended Session 1 to a whole day, considering the fact that it was still possible to use 3 more contact hours within the total study time of 28 hours. The whole-day Session 1 was aimed at helping participants to get over the initial hurdles of handling a new tool within the session, so the learning progress after Session 1 would be faster and with less frustration. This aim was consistent with the requirement for the Cycle-3 participants that they had to complete the draft version of the lesson plan (incl. the Coach activity) before Session 2.

Within the double time for Session 1, we extended Session 1 to a whole day, considering the fact that it was still possible to use 3 more contact hours within the total study time of 28 hours. The whole-day Session 1 was aimed at helping participants to get over the initial hurdles of handling a new tool within the session, so the learning progress after Session 1 would be faster and with less frustration. This aim was consistent with the requirement for the Cycle-3 participants that they had to complete the draft version of the lesson plan (incl. the Coach activity) before Session 2.

Within the double time for Session 1, we added a new, plenary, hands-on activity with step-by-step instruction. In this activity, all Cycle-3 participants practiced a simple modelling activity to get used to the Coach software and common features for the three Coach tools before they learnt one Coach tool by choice on their own. We chose Coach modelling among two other tools for this plenary, hands-on activity because of the following reasons:

- Modelling is relevant for both physics and chemistry teachers, whereas video measurement is not often used in chemistry education. Both physics and chemistry groups were also interested in data logging with sensors, but the whole-class hand-on practice with sensor measurement would require 9-12 sets of interface, sensors, and laboratory supplies in addition to the computers.
- The participants (Cycles 1 and 2) considered modelling the most difficult tool to use, whereas modelling is part of the new curriculum and included in the final examination.
- Modelling concepts (e.g. state variables, auxiliary variables, flows, constants, events) will be easier to understand if these concepts and basic manipulations in Coach are explained and demonstrated by the course instructor.

Therefore, this hands-on instruction was also to provide extra support for the group of the participants who decided to specialise in Coach modelling.

Because of the double time for Session 1, we allocated more time (100 instead of 70 minutes) for the group hands-on activity in which the Cycle-3 participants specialised in one tool by choice and practiced manipulation skills through the Coach tutorial activities. Moreover, at the end of Session 1, the course instructor instructed the participants about IBSE. This was the first part of the IBSE discussion moved forward from Session 2 of Cycle 2 in order to prepare the Cycle-3 participants with sufficient IBSE knowledge to propose the draft of the ICT in IBSE lesson plan before Session 2. These concerted revisions triggered opportunities in Session 2 for Cycle-3 participants to troubleshoot problems of the Coach activity with direct help of the course instructor.

**Did the revisions work out?** The revisions regarding the whole day for Session 1 and its components resulted in Cycle 3 in 5 participants (56% of N= 9) developing new Coach activities (Table 4.8) and 3 participants modifying the Coach exemplary activities. The following case illustrated positive effects of the new, plenary, hands-on activity about modelling and the longer time for individual practice with the ICT tool in Session 1:

In the discussion after the try-out, a Cycle-3 participant reported that she was personally interested in programming, but she had negative feelings about her earlier programming course at the university, so entered the ICT in IBSE course with some anxiety. However, she found this course very different and right away enjoyed learning the modelling tool. During Session 1, she
practiced all tutorial activities; even tried out and realised her own ideas (e.g. modifying the given model by additional events) with a little help of the course instructor; and looked very excited about what she could do. Later on, she developed her own, new Coach activity, which reflected her sufficient skills with the modelling tool (Figure 4.6a). Furthermore, she was able to stimulate and support her pupils in small groups to implement the Coach activity and then discuss the modelling results with peers and with the whole class (Figure 4.6b).

Figure 4.6. Screenshot of a Coach modelling activity about “pH calculation after dissolving HCl” of a Cycle-3 participant and photograph of her try-out with pupils working in small groups.

To conclude, the participants in Cycle 3 achieved a higher level of mastery with the ICT tool than those in Cycles 1 and 2. This conclusion resulted from the fact that there were more participants in Cycle 3 who could develop new Coach activities with the tool (Table 4.8) and could complete the cycle of designing and teaching the ICT in IBSE lesson within the intended time (Table 4.2).

c) After learning one tool in depth, were the participants confident to learn other tools by themselves?

**Methods.** Via the post-course questionnaire, we asked participants the following question, "In the course, you focussed on learning to use and apply only one of the Coach tools (i.e. data logging, video measurement, or modelling) in IBSE. How confident are you in learning by yourself and applying the other tool(s)?" (5-point scale, 1=not at all confident, 5=extremely confident). Based on participants’ responses, we computed the weighted average of confidence of the participants in each cycle.

**Results.** Almost all participants (32 out of 33) reacted to this Likert question. Already in Cycle 1, the participants were moderately to very confident in learning by themselves and applying ICT tools in which they did not specialise during the course (3.5 of the 5-point scale). This high confidence showed up again in Cycles 2 and 3. Among the three cycles, the Cycle-3 course reached to the highest confidence level of the participants and the least deviation between them (Table 4.9).
Table 4.9. The Dutch participants’ confidence in learning by themselves and applying ICT tools in which they did not specialise during the course.

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>12</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>• not at all confident</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>• slightly confident</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>• moderately confident</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>• very confident</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>• extremely confident</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Participants’ confidence level - Weighted average (SD)</td>
<td>3.5 (1.0)</td>
<td>3.3 (1.3)</td>
<td>3.8 (0.4)</td>
</tr>
</tbody>
</table>

Discussion. Cycle-3 participants achieved a more homogeneous and higher level of confidence about further learning ICT tools that they did not study in depth during the course. This resulted from a) the fact that the participants in Cycle 3 followed the one-tool specialisation better than those in Cycles 1 and 2 and b) the expanded first session (i.e. from a half to a whole day) which led to a higher skill level in the chosen tool.

d) Conclusions about operationalization of the depth-first principle

The above results of the formative evaluation regarding the depth-first principle show that operationalization of this principle was implemented faithfully in Cycle 3 regarding:

- the majority of participants followed the one-tool specialisation;
- the sufficient level of mastery with the ICT tool that most participants could achieve;
- the high level of participants’ confidence in learning by themselves and applying ICT tools in which they did not specialise during the course.

The cyclic refinement of the course led us to the conclusion about the following practical conditions for this principle to be implemented faithfully:

- participants should be made aware of the one-tool specialisation through the pre-course preparation,
- the first session should be one full day for participants to reach sufficient manipulation skills with the chosen tool,
- there should be opportunities for the participants to troubleshoot problems of the Coach activity for the lesson plan with the direct help in Session 2.

e) Recommendations

The participants faced problems in learning to use and apply the ICT tool during the course. Our solution was that we provided the participants with online support via email and direct support in Sessions 1 and 2. This solution worked out in Cycle 3, but there were still participants who did not follow the one-tool specialisation and not achieve a sufficient level of mastery with the ICT tool. Troubleshooting problems of the Coach activity via the email consultation took time, whereas the participants had limited time for the assignment. There is another solution, which we did not apply in this research. However, we would like to recommend for future optimisation of the course as follows:
Chapter 4

Across the three cycles, via live sessions, the assignment reports, and the email consultation, we recorded various participants’ problems regarding the Coach tool and the Coach activity. For future optimisation of the course, it might be useful to create a repository of these problems and related solutions in the form of descriptive text plus illustrative screenshots and video clips. This repository of most common problems can then be uploaded on the course website so that course participants can consult it. If the problem is already included in the repository, the participant will get immediate solutions and can keep progressing in the lesson plan. If the problem is not yet in the list, then the participants can ask the course instructor via email or in live sessions. This problem is then recorded and added to the repository for the next course.

4.2.4 About operationalization of the “ownership of learning” principle

a) Methods

In order to evaluate the implementation of the “ownership of learning” principle, we analysed if the participants did tailor and pursue their own learning during the course and if they found what they learnt relevant. Via assignment reports, we recorded their choices of the ICT tool to master (see Section 4.2.2) and of the ICT in IBSE lesson to develop and try out (see Section 4.3.1). In five sessions and after the try-out, the participants were asked to rationalise part of these choices considering their interest, needs, background, and/or teaching condition. Additionally, we observed if the participants worked actively in live group and individual activities and if they were proactive in preparing the ICT in IBSE try-out in the classroom. After the try-out, the participants were asked if they appreciated the relevance of IBSE as integral part of the ICT in IBSE course.

b) Results

In Session 1, the participants looked focussed during the individual and group practice with the Coach activities (Figure 4.7a), even not noticing that the time for this activity was up. Almost all participants actively consulted the course instructor about their particular problems with the ICT tool and about their ideas for the Coach activity (Sessions 1 and 2). Even after these live sessions finished, there were still three or four participants who lingered to discuss their individual assignments further and/or to borrow equipment for the try-out (Figure 4.7b).

Figure 4.7. Photographs of the participants practising manipulation skills in Session 1 (a) and lingering after the session to discuss their individual assignments with the course instructors (b).

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Here was a case of a participant actively pursuing a goal of her own:

At the end of Session 1, a Cycle-1 participant reported that she was inspired by vivid possibilities of data logging with sensors. She just thought of a Coach activity for height measurement triggered by a button press, and so asked us how to develop such Coach activity for her school’s open day. Via email, the course instructor instructed her how to develop the activity from scratch. The first version of her activity did not function well. Consequently, she discussed back and forth with us via email to troubleshoot problems of the activity. In time, she managed to finalise the Coach activity and execute the experiment with pupils and parents. In Session 2, she confidently presented details about the Coach activity: how to calibrate the ultrasound sensor, how to trigger via the light sensor, and how to analyse hundreds of data by histogram (Figure 4.8). She looked proud to share satisfaction of parents and interest of pupils about her measurement. She reacted to questions of fellow participants properly.

We did not require participants to apply the tool as soon as she did before Session 2. In this instance, the participant was motivated to learn by her own goal. Actually, she managed to pursue this goal and to achieve sufficient skills with the ICT tool in such a short time.

Of total 33 participants, 30 participants managed to pursue and complete their own classroom try-outs (see Section 4.2.1). Each participant carried out one ICT in IBSE try-out individually, except for only one case that two Cycle-1 participants designed and implemented one lesson together. Of total 29 try-outs, 17 lesson topics (59%) were in curriculum, and others were out of curriculum. About the context of the lesson, 19 try-outs (66% of N=29) were regular theory or laboratory lessons; 6 try-outs (21%) were with pupils’ research projects, and 4 others were with small group of 2 to 6 pupil volunteers. Regarding the use of the Coach activity, 21 try-outs (72%) let pupils to manipulate the ICT tool, whereas in 8 others, only the teacher manipulated the ICT tool in the form of interactive demonstrations (Table 4.10). Regarding the classification according to the inquiry continuum (see Chapter 2, Section 2.2.3), the lesson plans were distributed quite equally from interactive demonstration to bounded inquiry: 6 to 8 lessons per pattern; only two lessons took form of open inquiry (Figure 4.9).
Table 4.10. Number of the try-outs (of the Dutch participants) falling into each category by lesson topic, lesson context, and if pupils manipulated the ICT tool.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
<th>Total (N=33)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of classroom try-outs</strong></td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>Topic of the lesson</td>
<td>In curriculum 5</td>
<td>7</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Out of curriculum</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Context of the lesson</td>
<td>Regular theory lesson 2</td>
<td>5</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Regular laboratory lesson</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Optional lesson of 2 to 6 pupil volunteers</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Pupil research project</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Did pupils manipulate the ICT tool?</td>
<td>Yes</td>
<td>9</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>No*</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

(*) There were try-outs in which only the teacher manipulated the ICT tool in form of interactive demonstrations.

Figure 4.9. Number of Dutch ICT in IBSE lesson plans in each cycle categorised in certain patterns of inquiry teaching.

In fact, the individual participants themselves first proposed these choices based on their teaching conditions and their interest. After that they consulted the course instructor (in live sessions and/or via email) and the teacher mentor (in the school) to revise and finalise the lesson plan. The participants actually spent 4 to 7 hours (Table 4.5) to design the lesson plan. This amount was much more than the average of time they often invested to prepare a regular lesson as illustrated in the following discussion of a Cycle-3 participant:

“To prepare for a lesson, I often look for how my colleagues have taught the topic and then adapt their materials. ICT in IBSE is worthwhile but uncommon in my school. It was hard to come up with ideas: what do I want pupils to learn? What do I ask students? How do I use Coach modelling? It especially took me time to make a new activity, whereas I have only 30 - 40 minutes on average to prepare for one lesson. I had to make use much of my own time”

Through the email communication and discussions before and after the try-out, we noticed that the participants took responsibility and organised logistics for the try-out by themselves. Especially, eight participants had to borrow a class at different grade level from another teacher in order to find relevant topics for the ICT in IBSE try-out in the intended duration of the course. We attended 20 out of 29 try-outs and reviewed videos of 6 others. In these try-outs, we observed that the participants looked confident in implementing the lesson with pupils (Figure 4.10a).
In Session 3, almost all participants actively reported their classroom experience and commented on try-outs of fellow participants (Figure 4.10b). According to participants’ evaluation statements at the end of the session, they were content with what they had done with the try-out, intended to teach the Coach activity again with certain revisions, and gained motivations to apply the ICT tools further on their own. They also appreciated the reports of the other participants:

“It is nice to see many facets of inquiry and many options for ICT in IBSE through the try-outs of fellow participants. I did video measurement but felt that I can easily do modelling and sensor measurement as well.”

Moreover, we asked the following question to all nine Cycle-3 participants: “in view of the fact that student teachers struggle a lot with first year teaching pressures, should inquiry-based teaching be introduced to them and which level is suitable?”. All participants supported the introduction and assignment regarding IBSE as we did in the ICT in IBSE course. Two illustrations of the participants’ supportive responses:

• “You should know about IBSE, try it out, and train to teach with it. Teachers tend to stick to the system that works. If you are more experienced with traditional methods, you might think inquiry is not my kind of teaching. When I am learning to be a teacher, I am more open to try different things. Therefore, it is better to introduce inquiry teaching to beginning teachers. Additionally, it is hard to tell which level of IBSE is more suitable for student teachers. Some teachers just teach following inquiry ways naturally whereas some have to struggle a lot. It depends on how much common sense of teaching you have, how your teaching situation is.”

• “I think inquiry based learning/teaching can potentially bring many benefits to students’ learning process, if not let so open that students don’t experience success (at least to start off with). I feel inquiry based learning can positively influence students’ motivation, perhaps their understanding of physics’ subjects and/or how science/scientists work. If students are more motivated, they are more likely to be more involved, to do more work in the lessons, to pay more attention and to display less unwanted behaviour. This makes a beginning teacher’s work in many respects easier, not more difficult.”

c) Discussion

The participants actually made use of their freedom to tailor their learning and actively pursued their own choices through live sessions and individual assignments. The
student teachers appreciated their ownership of learning, considering their suggestions of more individual and group work, of more detailed feedback on individual assignments, and of more minds-on discussion on IBSE (Cycle 1) (see Section 4.2.2). In Cycle 3, the participants were aware of the one-tool specialisation and the classroom try-out before the course, so made suitable choices of the ICT tool, and managed to pursue this choice to achieve sufficient mastery of the tool (see Section 4.2.3).

While preparing for the try-out, the participants had to consider their teaching circumstances and recognised insufficient conditions (see Section 4.2.1). As an indispensable requirement, the participants had to make realistic choices (e.g. topic out of curriculum, try-out with small group of pupils, only the teacher manipulating the ICT tool). In Cycle 3, the participants were provided with sufficient time (i.e. between Sections 2 and 3) and adequate support (i.e. email and direct consultation, support materials). Consequently, the Cycle-3 participants invested sufficient time outside live sessions and managed to pursue their choices to complete the ICT in IBSE try-out, and so appreciated it as the main objective of the course.

d) Conclusions about operationalization of the “ownership of learning” principle

The above results of the formative evaluation regarding the “ownership of learning” principle show that operationalization of this principle was implemented faithfully in Cycle 3 regarding participants’ proactive participation and demonstrable outcomes in pursuing their own goals with respect to the course objectives. The cyclic refinement of the course led us to the conclusion about the following practical conditions for this principle to be implemented faithfully: a) participants’ awareness of the course scenario and their teaching conditions before the course and b) sufficient time and support for the participants to deal with insufficient conditions towards goals of their own.

4.2.5 About usefulness of the support materials

a) Methods

In order to evaluate if the support materials were useful, in each cycle, via the post-course questionnaire, we asked the following question to the participants: “to what extent are the support materials useful to you in learning to use and apply the ICT tools in the inquiry-based lesson?” To respond, the participants answered a 5-point scale (1 = not at all useful, 5 = extremely useful) for each material or selected the option: “I did not use it, so I have no idea”. Based on the participants’ feedback, we counted how many participants in each cycle used each material. After that, we computed the weighted average of usefulness for each material according to participants’ self-evaluation, disregarding ones who did not use. Additionally, in live sessions we observed how the participants made use of the support materials and collected their direct feedback on the use of these materials.

b) Results

Of all 33 participants, 32 participants (97%) responded to the question. Table 4.11 shows that almost all participants used the support materials during the course. In Cycle 1, the participants evaluated the Coach introductory, tutorial, and exemplary activities as very useful for them (4.2 to 4.5 of the 5-point scale). Evaluations of Cycle-2 and Cycle-3 participants about these activities remained positive (Table 4.11). Moreover, the following case supports
for usefulness of the Coach tutorial activities in particular for participants to learn manipulation skills:

Due to the duty in the school or illness, eight participants (4 in Cycle 1, 3 in Cycle 2, 1 in Cycle 3) were absent from Session 1. Of these eight participants, seven participants (87%) took the initiative to make an individual appointment with us to catch up for an hour. In each catch-up meeting, we explained the course assignments and let the participant practice one or two Coach tutorial activities with our direct help. Afterwards, the participant practiced other tutorial activities on their own to acquire manipulation skills. It was hard for them, but finally, six out of these seven participants managed to catch up with other participants and accomplish their classroom try-outs.

In all three cycles, many participants (9 out of 12 in Cycle 1, 9 out of 12 in Cycle 2, and 4 out of 9 in Cycle 3) selected or modified the Coach exemplary materials for their ICT in IBSE try-out (Table 4.8). Here was a particular reaction of a participant about the exemplary materials:

“The availability of “easy to adapt’’ exemplary activities is, I think, extremely useful. Teachers have in general very little time to prepare lessons and even less to think of and prepare completely new materials/activities. High pressure and high tempo at work don’t enable us to create even the simple yet exciting activities that have been shown to us in the course. Courses like this ICT in IBSE course really help in getting new ideas and energy to implement this kind of work and activities.”

The participants who were student teachers of chemistry desired to have more Coach exemplary activities on chemistry subjects; in the given list, the exemplary activities on physics were dominant.

**Table 4.11.** Number of the Dutch participants who used each type of support materials and their evaluation on the usefulness of each material to their learning during the course (5-point scale, 1 = not at all useful, 5 = extremely useful).

<table>
<thead>
<tr>
<th>Support materials</th>
<th>Number of participants using the material</th>
<th>Participants’ evaluation on usefulness of the material - Weighted average (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cycle 1 (N=12)</td>
<td>Cycle 2 (N=12)</td>
</tr>
<tr>
<td></td>
<td>Cycle 1 (N=12)</td>
<td>Cycle 2 (N=12)</td>
</tr>
<tr>
<td>Introductory slides</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Coach introductory activities</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Coach tutorial activities</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Coach exemplary activities</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Instructional video clips</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>IBSE-discussion worksheet*</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Forms for planning and self-evaluating the ICT in IBSE lesson</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

(*) The worksheet for IBSE discussion was developed after Cycle 1 according to suggestions of the Cycle-1 participants.

During Session 1, we observed that almost no participants used the instructional clips in practising the tutorial activities. They followed the text instruction embedded in the activity. When their trials did not work, they tried again or asked fellow participants and/or the course instructor. Table 4.11, however, indicates that 26 participants (81% of N=32) used the instructional clips. For these participants, the clips were from moderately to very useful.
(3.5 to 4.6 of the 5-point scale). Apparently, the clips were useful for the participants while practising Coach at home. There is a remarkable increase from Cycle 2 to Cycle 3 concerning participants’ evaluation on the usefulness of the clips. In fact, we did not revise the clips or use more of those in Cycle 3. This difference might be caused by either having different participants or by changes we made for the scenario (e.g. more extensive introduction and practice of Coach in Session 1), but we did not know for sure the mechanism why.

The worksheet for IBSE discussion was developed after Cycle 1 according to the suggestion of participants (see Section 4.2.2) and used in Session 2 of Cycles 2 and 3. The participants actively addressed three discussion questions in the worksheet with the whole class under the coordination of the course instructor. They evaluated this material as moderately or very useful (3.5-3.9 of the 5-point scale, Table 4.11):

- "I found the example of activity about Boyle’s law useful to understand what inquiry can look like when coupled to a Coach activity."
- “The example of Boyle’s law is useful. It shows an inquiry process: first, gaining conceptual knowledge, doing predictions, discussing how to research (what to change, what to measure), and then doing the experiment. There can be a bit of cookbook rules in it as long as there is also "minds-on", depending on the learning goals”.

c) Discussion

Already in Cycle 1 as well as in the two subsequent cycles, the Coach activities proved to be very useful for participants in learning to use and apply the ICT tool, especially for self-study outside live sessions. This resulted from good quality of these materials, which had been developed and optimised through previous projects. The introductory slides and forms for planning and self-evaluating the ICT in IBSE lesson were also useful but received lower ratings (Table 4.11). Unlike the Coach activities, these materials were not self-contained and were used in interaction with the course instructor and so these had a different function.

Considering the fact that the support materials fulfilled the requirements of the course to a large extent already in Cycle 1, the course optimisation was focused on fine-tuning the course scenario to make use of these materials better rather than revising the support materials themselves. The only new material we developed after Cycle 1 was the IBSE-discussion worksheet, which proved to be useful to the participants. Positive effects of the support materials as a main part of the course logistics showed up again in Cycles 2 and 3. Importantly, these materials actually supported the participants to achieve the course objectives to sufficient extent (see also Section 4.3). The online support (incl. the course website and the email consultation) enabled the participants to access and make use of the support materials sufficiently in Cycle 3 (see Section 4.2.2).

d) Conclusions about usefulness of the support materials

In all three cycles, the support materials were useful for participants, especially in learning outside live sessions mostly on their own. The support materials together with the online support created the practical conditions for the “distributed learning” and “ownership of learning” principles to be implemented faithfully in Cycle 3.
4.2.6 Optimised scenario of the course through the three cycles

Table 4.12 summarises the Cycle-3 scenario, which was optimised through the three first cycles of the Dutch ICT in IBSE course.

Table 4.12. Summary of the Cycle-3 scenario of the Dutch ICT in IBSE course.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time frame*</th>
<th>Participants’ activities</th>
<th>Format</th>
</tr>
</thead>
</table>
| Pre-course preparation**     | 1 week      | • Reading the course description.  
                             |             | • Reading the introductory slides.  
                             |             | • Installing the Coach software  
                             |             | • Practising the Coach introductory activities.  
                             |             | • Exploring the teaching conditions to choose which  
                             |             | ICT tool to specialise in during the course.  | Individual |
| Session 1 (a day)            | 6 hours     | • Listening to the introduction and demonstration  
                             |             | of the three ICT tools.  | Plenary |
|                              |             | • Practising basic manipulation skills with the  
                             |             | Coach software following step-by-step  
                             |             | instruction  | Plenary |
|                              |             | • Choosing one of the three ICT tools and  
                             |             | practising manipulation skills through the  
                             |             | introduction, tutorial and exemplary Coach  
                             |             | activities.  | Group of two  
                             |             | • Listening to the instruction about IBSE and  
                             |             | examples.  | or individual |
|                              |             | • Receiving Assignment 1 and Assignment 2.   | Plenary |
| Assignment 1**              | 2 weeks     | • Part a: continuously practising the chosen ICT  
                             |             | tool to acquire the sufficient manipulation skills  
                             |             | • Part b: preparing the Coach activity and writing a  
                             |             | draft version of the learning scenario for the  
                             |             | lesson plan  
                             |             | • Writing Assignment-1 report  | Individual |
| Session 2 (a half day)       | 3 hours     | • Discussing manipulation problems related to  
                             |             | Assignment 1.  | Group |
|                              |             | • Discussing the IBSE exercise.  | Plenary |
|                              |             | • Discussing and optimising the Coach activity  
                             |             | and learning scenario for the lesson plan of  
                             |             | individual participants.  | Group |
| Assignment 2**              | 9 weeks     | • Trying out the ICT in IBSE lesson with pupils  
                             |             | • Self-evaluating the ICT in IBSE try-outs (i.e.  
                             |             | main part of Assignment-2 report)  | Individual |
| Session 3 (a half day)       | 3 hours     | • Reporting and evaluating the try-outs.  | Group |
|                              |             | • Discussing what are learned from the course.  | Plenary |

(*) Total study time (i.e. 28 hours) was divided into 12 contact hours and 16 hours outside live sessions. The course was spread over 11 weeks. “Hours” mean actual hours of work within the course. “Weeks” indicate a time period during which some of the time would be spent on the course assignments and other time on other activities unrelated to the course.

(**) While preparing for the course and carrying out individual assignments, the participants were encouraged to use the support materials and the online support.

Compared to the Cycle-1 scenario (Table 3.2), the Cycle-3 scenario (Table 4.12) was revised as follows:

The timeframe. Session 1 in Cycle 3 took a whole day. Duration between Sessions 2 and 3 increased to 9 weeks.
Individual assignments. In Cycle 3, the participants had to decide before Session 1 which tool to specialise in (pre-course preparation) and to start designing the lesson plan as part of Assignment 1 (between Sessions 1 and 2).

Session 1. In Cycle 3, the participants got started with the Coach software following the step-by-step instruction (new component), and then specialised in one ICT tool (same component but with more practice time).

Session 2. First, manipulation problems were discussed in the group of the Cycle-3 participants who practiced the same tool. Second, the focus of the instruction about IBSE was shifted to an exercise on how to change a cookbook laboratory to become more inquiry. Last, the Cycle-3 participants consulted the course instructor to troubleshoot problems of the Coach activity and to improve the learning scenario for the lesson plan.

Session 3. In Cycle 3, the participants reported their try-outs in the group of participants who taught the same subject and/or used the same ICT tool.

The online support. The online platform took form of a webpage. Emails became the main means for the online consultation.

These revisions resulted in faithful implementation of the course in Cycle 3. The course scenario proved to be optimised through the three cycles, and the optimised scenario (Table 4.12) with the support materials provided the practical and necessary conditions for sufficient operationalization of the four principles in the Dutch context.

4.3 Summative evaluation of the Dutch ICT in IBSE course

This section presents a) the extent to which the four course objectives have been attained and discusses b) which pedagogical principles and support materials contributed to the achievement of each objective. We present the course outcomes in Cycle 3. For certain evaluation points, we also mention outcomes of the course in Cycles 1 and 2.

4.3.1 About participants’ awareness of educational benefits of the ICT tools in science education

a) Methods

Via open-ended questions in the post-course questionnaire, we asked the Cycle-3 participants to indicate educational benefits of the use of data logging, video measurement, and modelling in science education. After that, we examined the particular benefits of the ICT tool each participant pointed out. Next, we compared these enumerated benefits to ones that were discussed in the literature and reviewed in Chapter 2. For example, the ICT tools enabled authentic learning, inquiry practices, and better understanding.

b) Results

Seven out of nine Cycle-3 participants (78%) reacted to the questions; each respondent enumerated two to four benefits of the ICT tools, most of which were discussed in Chapter 2, Section 2.1.2. The participants pointed out benefits of not only the tool in which they specialised but also the two others. Of 7 respondents, 4 participants (57%) enumerated the benefit in bringing real life into the classroom and letting pupils work with tools similar to
those of scientists (authenticity). The benefits of stimulating pupils to exercise inquiry practices and of improving conceptual understanding were mentioned by 5 participants and 4 participants respectively (71% and 57% of N=7). About half of the respondents (3 out of 7) remarked time efficiency of using the ICT tools in laboratory demonstration and/or in practical work. Furthermore, most respondents (6 out of 7) pointed out motivational effects of using the ICT tools: making school science more exciting and meaningful and seducing pupils to pursue science-related careers. Considering all respondents together, the enumerated benefits covered almost all the literature review of benefits of the ICT tools in Chapter 2. Two particular responses were:

• “Using computers is a motivating factor for the lesson. The students enjoy the lesson more, and that increases their output of learning. Data logging is very handy saving a lot of handwork to create graphs. Students get a nice graph after relatively little work. Such positive experiences are stimulating. Video measurement is a lovely tool to answer every day questions, e.g. how hard did Zlatan kick that ball? Modelling is more complex but yields the biggest rewards as well. Once the students can understand most models, then concepts can become thoroughly fortified into their brains after modelling with them”;

• “Data logging and video measurement enable to couple events from "real life" with theory learnt in the lessons; increasing motivation and self-confidence in students (and beginning teachers!). Modelling enables to understand how scientific process works and understand theory better by having to build models that reproduce real measurements. These ICT tools help to acquire some level of independence in interpreting and analysing models and data and make school science more attractive. Moreover, for students taking nature profiles, learning to use the ICT tools is absolutely essential. And perhaps if students got used to it earlier on, maybe more would choose technical studies?”

c) Discussion and conclusions

Discussion. The above data show participants’ awareness of the educational benefits of the ICT tools in Cycle 3. This resulted from the fact that:

• the participants studied possibilities of the three tools through the introductory slides, the introduction plus demonstrations in Session 1, and the Coach exemplary materials;
• all Cycle-3 participants tried out these possibilities with pupils;
• a considerable number of Cycle-3 participants (5 out of 9, Table 4.8) realised new possibilities of the ICT tool in their new Coach activities.

Moreover, through reflections on the try-outs of fellow participants in Session 3, the participants possibly became aware of more benefits of the two tools in which they did not specialise. This awareness of the participants regarding benefits of all three ICT tools then probably resulted in their motivations to learn the ICT tools further after the course (see Section 4.3.4).

Conclusions. The course achieved the level of the awareness objective that participants could enumerate one or two relevant benefit(s) of not only the specialised tool but also each of the two others. This outcome matched with our expectation. This achievement resulted from the sufficient operationalization of the “one theory-practice
cycle” and “depth first” principles in Cycle 3 as well as the use of the introductory slides and the Coach exemplary activities.

4.3.2 About participants’ skills to operate the ICT tools

a) Methods

To arrive at the conclusion about participants’ skills to operate the ICT tool, we evaluated the following aspects:

- To what extent were the participants confident in manipulating the tool?
- How could the participants manipulate the tool and/or support their pupils’ manipulations of the tool in the classroom?
- Could the participant develop a new Coach activity or at least modify an exemplary activity for the ICT in IBSE lesson?
- Could the participants troubleshoot problems in applying the ICT tool?

Via the pre-course questionnaire, we asked the participants to report about their confidence level with regard to particular manipulations of each of the three ICT tools on a 5-point scale (1 = not confident at all, 5 = extremely confident). We repeated these questions in the post-course questionnaire. For each tool, based on the participants’ pre- and post-ratings for each item (i.e. each manipulation), we computed the weighted average of pre- and post-confidence and the normalised gain for each manipulation for two groups. The first group included participants who tried out with the ICT tool (i.e. data logging: 1 participant, video measurement: 2 participants, and modelling: 6 participants). The second one consisted of other participants, who did not specialise in the tool (Table 4.13).

Additionally, we observed the participants’ and/or their pupils’ manipulations of the ICT tool in the try-outs to check a) if these manipulations yielded sufficient experiment/model data and b) if the participants came across and/or could troubleshoot problems of the Coach activity in the classroom. Additionally, via the email consultation and in Sessions 2, we checked if the participants encountered and/or solved problems in preparing the Coach activity for the try-out. Based on the submitted lesson plan (incl. the Coach activity), we examined if the Coach activity was selected or modified from the given one or totally new (see the data in Section 4.2.3).

b) Results

The normalised-gain values in Table 4.13 show that through the course, the Cycle-3 participants became much more confident in manipulating the ICT tool, which they tried out in the classroom. They gained confidence, more for basic manipulations (e.g. Table 4.13: 1.1-1.4, 2.1-2.3, 3.1-3.3) and less for advanced manipulations (e.g. Table 4.13: 1.5-1.6, 2.5, 3.4). Regarding the confidence level after the course, the Cycle-3 participants felt very confident about basic manipulations with the ICT tool in which they specialised during the course (4.0-5.0 of the 5-point scale, Table 4.13).
Table 4.13. Confidence levels before and after the course and the normalised gains of Cycle-3 participants for particular manipulations of the tool which they tried out and of the two others (5-point scale, 1=not confident at all, 5 = extremely confident).

<table>
<thead>
<tr>
<th>Manipulation</th>
<th>Confidence level of participants who tried out the tool</th>
<th>Confidence level of participants who did not specialise in the tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Data logging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1. Connecting sensors and an interface to a computer</td>
<td>Pre: 4.0, Post: 5.0, Normalised gain*: 100%</td>
<td>Pre: 1.7, Post: 2.1, Normalised gain: 12%</td>
</tr>
<tr>
<td>1.2. Setting sensor connection in the software</td>
<td>Pre: 2.0, Post: 4.0, Normalised gain*: 67%</td>
<td>Pre: 1.7, Post: 2.3, Normalised gain: 18%</td>
</tr>
<tr>
<td>1.3. Setting time-based measurement</td>
<td>Pre: 2.0, Post: 4.0, Normalised gain*: 67%</td>
<td>Pre: 1.9, Post: 2.3, Normalised gain: 13%</td>
</tr>
<tr>
<td>1.4. Setting event-based measurement</td>
<td>Pre: 2.0, Post: 4.0, Normalised gain*: 67%</td>
<td>Pre: 1.4, Post: 2.3, Normalised gain: 25%</td>
</tr>
<tr>
<td>1.5. Setting a measurement based on a trigger event</td>
<td>Pre: 2.0, Post: 3.0, Normalised gain*: 33%</td>
<td>Pre: 1.6, Post: 2.1, Normalised gain: 15%</td>
</tr>
<tr>
<td>1.6. Determining the calibration factors of a sensor</td>
<td>Pre: 2.0, Post: 3.0, Normalised gain*: 33%</td>
<td>Pre: 1.4, Post: 2.0, Normalised gain: 17%</td>
</tr>
<tr>
<td>2. Video measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1. Making scale settings</td>
<td>Pre: 1.5, Post: 4.5, Normalised gain*: 86%</td>
<td>Pre: 1.7, Post: 2.5, Normalised gain: 24%</td>
</tr>
<tr>
<td>2.2. Specifying features of the coordinate system</td>
<td>Pre: 1.0, Post: 4.5, Normalised gain*: 88%</td>
<td>Pre: 1.7, Post: 2.3, Normalised gain: 18%</td>
</tr>
<tr>
<td>2.3. Setting time calibration for video</td>
<td>Pre: 1.0, Post: 4.5, Normalised gain*: 88%</td>
<td>Pre: 1.5, Post: 2.3, Normalised gain: 23%</td>
</tr>
<tr>
<td>2.4. Performing perspective correction</td>
<td>Pre: 1.0, Post: 4.0, Normalised gain*: 75%</td>
<td>Pre: 1.3, Post: 2.3, Normalised gain: 27%</td>
</tr>
<tr>
<td>2.5. Correcting video points by dragging wrong measured points to the correct position</td>
<td>Pre: 1.5, Post: 3.5, Normalised gain*: 57%</td>
<td>Pre: 1.5, Post: 2.5, Normalised gain: 29%</td>
</tr>
<tr>
<td>2.6. Setting point tracking by which measurement is performed automatically</td>
<td>Pre: 1.5, Post: 4.5, Normalised gain*: 86%</td>
<td>Pre: 1.3, Post: 2.2, Normalised gain: 24%</td>
</tr>
<tr>
<td>3. Modelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1. Using a given model to understand a phenomenon</td>
<td>Pre: 3.5, Post: 4.5, Normalised gain*: 67%</td>
<td>Pre: 3.3, Post: 4.3, Normalised gain: 59%</td>
</tr>
<tr>
<td>3.2. Exploring to gain insight into a given model</td>
<td>Pre: 3.5, Post: 4.5, Normalised gain*: 67%</td>
<td>Pre: 3.7, Post: 4.0, Normalised gain: 23%</td>
</tr>
<tr>
<td>3.3. Making a small change to a given model</td>
<td>Pre: 3.3, Post: 4.8, Normalised gain*: 88%</td>
<td>Pre: 3.0, Post: 3.3, Normalised gain: 15%</td>
</tr>
<tr>
<td>3.4. Developing a graphical model</td>
<td>Pre: 2.0, Post: 3.8, Normalised gain*: 60%</td>
<td>Pre: 3.0, Post: 3.0, Normalised gain: 0%</td>
</tr>
</tbody>
</table>

(*) Normalised gain = (post - pre)/(maximum - pre) (maximum of the rating scale is 5)

We observed all nine try-outs in Cycle 3. In two try-outs, the student teachers executed the Coach experiment/model smoothly and collected sufficient data for interactive demonstrations and discussions with pupils. In seven others, the teacher assigned pupil-groups to manipulate the ICT tool. Five student teachers (out of 7) wrote text instructions with illustrative screenshots for the Coach activity (Figure 4.11). These instructions were so instructive that pupil groups with no experience with Coach could follow and execute the Coach activity with a little help of the teacher. These groups then got sufficient
model/experiment results for report and discussion (Figure 4.17). Meanwhile, two other participants (out of 7) did not prepare either instructions of necessary manipulations or the pupils’ prerequisite skills before the try-out. In their try-outs, they were unintendedly too busy reacting to questions of different groups of pupils about how to manipulate the software. Eventually, just one or two groups got some data, and there was no time left for discussions.

In Cycles 1 and 2, we observed almost all try-outs (9 out of 10 in Cycle 1 and 8 out of 10 in Cycle 2) and witnessed the participants’ confidence in manipulating the ICT tool and/or supporting pupils’ manipulations. However, we observed six cases of the try-out in which the participants could not answer pupils’ questions about Coach advanced features. For example, “How to rotate the coordinate system in order to align the x axis in parallel with the incline?” (Try-out on video measurement, Cycle 1), “How to do the function fit with a part of the graph? (the other part was not related to the phenomenon to be investigated)” (Try-out on data logging, Cycle 1). The participants in these cases tried their tentative solutions with the Coach software for a while, but their trials did not work.

In Cycle 3, regarding the Coach activity in the classroom, we did not observe serious problems that the participants could not solve. However, we still recorded specific troubles of six participants (out of 9) in preparing the Coach activity for the try-out (see also Section 4.2.3b). These six participants first attempted to troubleshoot the problems themselves but failed. After that, two participants consulted the course instructor via email, and the four others left the problems for direct consultation in Sessions 2. With help of the course instructor, the participants were successful in troubleshooting these problems. Here are two particular cases:

**Case 1.** A participant wanted to try out the given Coach model of the cooling of a cup of coffee for her class. However, she was uncertain if she could react properly to pupils’ questions about Coach modelling. Consequently, she tried to re-create a model from scratch. After running the replicated model, she got an unexpected graph in which temperature seemed to remain constant
over time (Figure 4.12). Meanwhile, the given model produced a nice curve of temperature vs. time, decreasing from initial temperature to room temperature, then remaining constant. She checked constants, variables, and connections carefully again to ensure that they were the same as those in the given model. Executing the model again, she still got the “strange” graph, so she lost her confidence and emailed for help. The course instructor then found out that she left the execution time at 10s. Therefore, the change of temperature was not visible in the graph. The participant was suggested to change the execution time; she then got the point and fixed the problem easily. The challenges to the participant in the example were not only about becoming familiar with technical details of the modelling tool, but also about learning to model a phenomenon, considering various issues such as concepts, laws of science, and actual parameters. She had to learn both aspects.

Figure 4.12. Screenshot of a Coach activity for modelling cooling of a cup of coffee.

Case 2. A Cycle-3 participant designed an experiment with Coach data logging about resonance of a glass (i.e. new Coach activity). At home, he tried out the same set-up with two different measurement devices (incl. Coach), but got two different results for the resonance frequency. The Coach result looked incorrect. He struggled in checking the set-up, redoing several times, but still getting the wrong result. Eventually, he brought this trouble to Session 2 and asked for help. The course instructor then found out that the resonance frequency was expected to be about 800 Hz (Figure 4.13), whereas the sampling frequency in his measurement setting was only 50 Hz (default). He got this point and increased the sampling frequency to 5000 Hz. Consequently, the Fourier transform of the sound signal yielded an acceptable value of the resonance frequency. For the try-out, he highlighted this issue in the text instructions for his pupils’ practical work (Figure 4.11). The participant, in this case, had sufficient manipulation skills to develop his own, new Coach activity, but he still needed experience of troubleshooting which requires the understanding of how Coach samples measurements.

Figure 4.13. A participant’s Coach activity for measuring the frequency of resonance of a glass.
c) Discussion, conclusions, and recommendations

**Discussion.** Data about the Cycle-3 participants’ manipulations of the ICT tool from the classroom observation were in line with those from the pre- and post-questionnaire, so we conclude that the Cycle-3 participants mastered basic manipulation skills with the tool in which they specialised. This conclusion was also supported by the fact that most Cycle-3 participants could develop their new Coach activities (5 out of 9) or modify the Coach exemplary activities (3 out of 9) (Table 4.13).

Interestingly, the participants became slightly more confident in manipulating the ICT tools in which they did not specialise during the course (Table 4.13). This resulted from the fact that the participants a) performed the Coach introductory activities before the course; b) practiced basic manipulation skills with the Coach software following step-by-step instruction (about Coach modelling) in Session 1; and c) witnessed what fellow participants had done with Coach in their try-outs in Session 3. However, the significant increase (Table 4.13) in manipulation skills was gained as the Cycle-3 participants actually took the following successive steps to learn the ICT tool in depth:

- Practising the Coach tutorial activities for half of the whole-day session 1 and for 3-4 hours after this session (Table 4.5);
- Preparing/modifying/developing the Coach activity for the lesson plan, using the chosen tool (Table 4.8);
- Teaching with the chosen tool in the classroom (100% of N=9).

During the course and in the realistic teaching conditions, the participants had to learn to use and apply the ICT tool as independent learners; and this independent learning consisted of sequences of trying, experiencing troubles, troubleshooting, and trying again. In addition to the initial hurdles regarding new ICT concepts and skills (see Section 4.2.3b), the participants encountered problems beyond the basic manipulation skills. Based on recorded problems of the participants across the three cycles, we analysed the complex nature of this type of problems that involves:

- Advanced features of the ICT tool (e.g. how to add the empirical graph to the modelling activity and compare it with the modelling graph; how to make control bars to change constants and initial values of variables of the model);  
- Participants’ understanding of the phenomenon (i.e. concepts, laws, and events) to be experimented or modelled with the ICT tool and general experimentation/modelling skills;
- Participants’ knowledge of mental model behind the digital tool that enables a) collection and modelling of information about the phenomenon (sampling, digitalisation, numerical iteration) and b) representation, analysis, and processing of the collected/modelled data (see Chapter 2, Section 2.1.2).

Therefore, we label these as “Technological Content Knowledge” (TCK) problems. The TCK problems occurred when the participants modified or developed the Coach activity for the ICT in IBSE try-outs and/or interpreted the resulting data of the Coach activity.

The participants (Cycle 3) did not yet reach the expert level of the ICT-mastery objective that enabled them to troubleshoot problems of the Coach activity on their own. As we predicted, through the limited time, the course could not bring the participants to the level
of a Coach expert with troubleshooting skills. However, the level that the participants reached within the course was sufficient for them to teach with the ICT tool after the course and to learn the ICT tools further. This would enable the participants to gain higher mastery of the ICT tools on their own. This continuous learning was possible with the available support materials and the Coach helpdesk for email consultation (helpdesk@cma-science.nl), and it actually occurred in the one to two years after the course (see Section 4.3.4).

**Conclusion.** The course achieved its ICT mastery objectives from the adopter-user level (1 out of N=9) to the adapter-user level (3 out of N=9) and the creator-user level (5 out of N=9). These achieved levels correspond to the basic Coach skills that enabled the participants to prepare/modify/develop and execute the Coach activity in the classroom, using their chosen tool. These basic skills were sufficient for the participants to study the ICT tools further after the course. This achievement matched with our expectation. It resulted from the sufficient operationalization of the “depth first” and “distributed learning” principles in Cycle 3 as well as the relevant use of the Coach introductory and tutorial activities.

**Recommendations.** Encountering frustrations is part of learning any sophisticated ICT tool; the user has to get through the problems to grow in troubleshooting ability. With the boundary condition of a short course, we could not spend sufficient time for the participants to learn these troubleshooting skills. In order to enable the participants to complete the Coach activity early enough for the try-out (before Session 3), we helped them to get over the TCK problems through direct and/or email consultations. For future optimisation of the course, we would like to recommend another solution, which we did not apply in the Dutch case study. This solution is as follows:

Based on the recorded TCK problems of the participants, we might develop three incomplete or problematic Coach activities corresponding to the three tools as troubleshooting exercises (i.e. computer performance test, see Chapter 3, Section 3.1.4). At the beginning of Session 2, we might ask individual participants to improve one of these incomplete or problematic activities independently as a 20-minute test of whether or not the participants already gain sufficient skills with the specialised tool after Assignment 1. This short exercise can be considered as a learning tool that helps the participants to be aware of what they have to think about while facing problems (e.g. right sensors, sufficient sampling rate, and correct time calibration). After trying to solve the given, reasonable problems and discussing solutions with the course instructor afterward, the participants might be more encouraged and more creative in troubleshooting.

**4.3.3 About participants’ ability to design, implement, and evaluate an ICT in IBSE lesson**

To arrive at the conclusion about participants’ ability to design, implement, and evaluate an ICT in IBSE lesson within the course, we evaluated the following three aspects:

a) Could the participants operationalise inquiry opportunities with the ICT tool in the lesson plan? (Ability to design)

b) Could the participants implement inquiry opportunities with the ICT tool faithfully in the classroom try-out? (Ability to implement)

c) Could the participants self-evaluate implementation of inquiry opportunities with the ICT tool in their try-out? (Ability to evaluate)
**Chapter 4**

*a) Could the participants operationalise inquiry opportunities enhanced by the ICT tool in the lesson plan?*

**Methods.** Based on each lesson plan (Form 2), we coded which inquiry components (out of 22) were stated as learning goals of the lesson (Stage 1). Next, we reviewed the activity specification, including the teacher’s questions and instructions and pupils’ activities and tasks. This specification was intended in the learning scenario (i.e. last part of the lesson plan), the Coach activity (incl. its embedded text instruction), worksheets, and/or presentation slides. Reviewing the activity specification was to examine and code which inquiry components (out of 22) were operationalised as pupils’ learning opportunities in the form of questions, tasks, and activities during the lesson (Stage 2). After that, we computed how many inquiry components on average were operationalised in the lesson plan. Additionally, we determined which inquiry components were focused on by most participants. By comparing the two types of coding data (Stage 1 - intentions versus Stage 2 - actual learning opportunities) (Table 4.14), we checked if the participants operationalised all inquiry goals into particular learning opportunities.

**Results.** In Cycle 3, all nine participants completed their lesson plans (N=9) and operationalised about 8 (SD=2) inquiry opportunities per lesson (per participant). Four inquiry components were operationalised most frequently in the nine lesson plans as follows:

- **Component 1.4:** predicting results of the experiment/model based on its design (6 out of 9)
- **Component 2.1:** manipulating software/apparatus to construct and/or execute the experiment/model (7 out of 9)
- **Component 2.2:** observing and/or measuring experimental variables or determining resulting values of modelling variables (8 out of 9)
- **Component 3.3:** determining qualitative and/or quantitative relationships (7 out of 9)

Operationalised in 4 to 5 out of total 9 lessons (Figure 4.15) were components: 1.2, 1.3a, 1.3b, 2.3, and 3.4. These nine components are very relevant and feasible for pupils to exercise in an ICT in IBSE activity. The following example illustrates how a Cycle-3 participant focussed on several inquiry components and operationalised realistic but relevant learning opportunities for pupils (Lesson plan 7, Table 4.14):

A Cycle-3 participant chose a well-known event: Felix Baumgartner’s space jump as the lesson context in which pupils investigated realistic fall in air of increasing density. She developed a new Coach activity in which she used real data from the Baumgartner website and added these to the background of the modelling graph to compare modelling and real-time data. In the classroom, first she asked pupils to sketch x-t and v-t graphs of a fall (i.e. **component 1.2**) and then demonstrated with Coach that these graphs based on a free fall model did not match with the real data of the Baumgartner jump. After that she asked pupils in small groups to represent the model of the jump with post-its, considering realistic factors. Then she discussed these in plenary (i.e. **component 1.3a**) (Figure 4.14). She monitored the discussion and demonstrated with the Coach modelling activity through series of question followed by demonstration: “if you add friction, what will happen in the model?”, “If you consider the difference in atmospheric density during the fall, what will happen in the model?”. The pupils observed the modelling graphs and reacted to these questions (i.e. **components 2.2, 3.3**) (Figure 4.14). In this try-out, pupils without modelling experience were involved in a progressive modelling process, and the only one using Coach was the teacher. The emphasis was on modelling concepts and not on how to handle the software.

This is a nice example of teaching a modelling lesson for the first time for both the teacher and pupils. She published this successful experience of designing and teaching an inquiry-
based lesson with Coach modelling in an article in the Dutch science-education journal (NVOX, Teixeira et al., 2015).

\[ \text{Figure 4.14. Photographs illustrating the topic (i.e. Felix Baumgartner’s space jump) and classroom activities within a try-out of interactive demonstrations with the modelling tool.} \]

\[ \text{Figure 4.15. Number of Dutch lesson plans (out of total 9 in Cycle 3) in which each inquiry component (1.1 to 4.4) was operationalised as a learning opportunity (and not a prescriptive recipe) for pupils.} \]

The list of 22 categories of inquiry skills within the ICT in IBSE activity:

1. **Conception, planning and design**
   - the pupil
     - 1.1 formulates a question
     - 1.2 formulates an hypothesis or expectation
     - 1.3a defines variables of experiment/model
     - 1.3b defines how each variable will be measured or modelled
     - 1.3c defines procedures to analyse experimentation/modelling data
     - 1.4 predicts results of experiment/model based on its design

2. **Execution of experiment/model**
   - the pupil
     - 2.1 manipulates software and/or apparatus
     - 2.2 measures/determines values of variables
     - 2.3 records experimentation/modelling data
     - 2.4 decides/explains experimentation/modelling techniques
     - 2.5 works according to the own design

3. **Analysis and interpretation**
   - the pupil
     - 3.1 chooses representations of data
     - 3.2 determines accuracy and precision of data
     - 3.3 determines relationships
     - 3.4 compares the results to the hypothesis/prediction
     - 3.5 explains experiment/modelling results
     - 3.6 discusses limitations of the experiment/model
     - 3.7 proposes generalizations of the results

4. **Applications and follow-up**
   - the pupil
     - 4.1 predicts on basis of obtained results
     - 4.2 formulates new questions
     - 4.3 formulates hypotheses for follow-up
     - 4.4 applies the techniques to a new problem
Table 4.14. Number of inquiry components, which were stated as learning goals and/or operationalised as learning opportunities in each lesson plan in Cycle 3 (a participant designed a lesson plan).

<table>
<thead>
<tr>
<th>Lesson plan</th>
<th>Number of inquiry components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>stated as learning goals, but not operationalised as learning opportunities (only Stage 1)</td>
<td>operationalised as learning opportunities, but not stated as learning goals (only Stage 2)</td>
</tr>
<tr>
<td>Lesson plan 1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Lesson plan 2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Lesson plan 3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Lesson plan 4*</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Lesson plan 5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Lesson plan 6*</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Lesson plan 7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lesson plan 8</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lesson plan 9*</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>SUM</td>
<td>7</td>
<td>33</td>
</tr>
</tbody>
</table>

(*) Three lesson plans (no. 4, 6, 9) did not state inquiry goals explicitly. The lesson numbers refer to lessons of different participants.

Of total 71 inquiry components operationalised as learning opportunities per 9 lesson plans, 33 inquiry components (46%) were not stated as learning goals of the lessons. Out of total 9, 3 lesson plans (no. 4, 6, 9) did not state inquiry goals explicitly although this was required on the lesson-plan form. Of three participants who did not state inquiry goals explicitly, two participants submitted their lesson plans just a night before the try-out, so perhaps they did not spend sufficient time to write the plan. The other participant spent much time to prepare for the try-out, but she thought that teaching well in the classroom was much more important than writing a good plan, so she did not write down a thorough lesson plan.

Out of total 9, 4 lesson plans (no. 2, 3, 7, 8) showed a clear operationalization of all stated inquiry goals, whereas in 2 other lessons (no. 1, 5) just part of their inquiry goals (10 out of 17) were operationalised (Table 4.14). The two following cases illustrated the inconsistency between statements of inquiry goals and operationalised inquiry opportunities in most lesson plans:

**Case 1.** A Cycle-3 participant planned to demonstrate a video measurement of a shuttlecock falling in air and plot y-t and vy-t graphs (Lesson plan 2, Table 4.14). The text instructions in the Coach activity (Figure 4.16) showed that the teacher intended to ask pupils to observe the graphs and address the questions: “what can you deduce about the shuttlecock's speed during its motion?”, “How will the velocity of the shuttlecock change in time?”. This was indeed an operationalised opportunity for pupils to exercise “Determining qualitative relationships” via graphs (i.e. component 3.3). However, this inquiry component was not stated as a learning goal of her ICT in IBSE lesson.
Case 2. In the objective section (Lesson plan 1, Table 4.14), a Cycle-3 participant stated inquiry components 1.1 and 1.2 as learning goals of his ICT in IBSE lesson (i.e. the pupil formulates a question to be investigated and a tentative answer to the research question). In the activity specification, the participant intended to let pupils work in small groups, following a worksheet to execute a prepared Coach activity and to collect data for further analysis and report (i.e. practical work). The worksheet, however, indicated the research problem explicitly: “Het doel van dit experiment is om een verband tussen de hoeveelheid vloeistof in het glas en de frequentie van de geproduceerde toon te vinden.” [The goal of this experiment is to find out the relationship between the amount of liquid in the glass and the frequency of the tone that is produced]. In this case, intentions for inquiry components 1.1 and 2.2 were not operationalised in the activity specification; pupils would not have any opportunities to exercise these inquiry components.

Discussion. Considering the course requirements, the Cycle-3 participants actually operationalised several inquiry opportunities (Mean=8, SD=2) with the ICT tool, and the inquiry components operationalised by most participants were worthwhile. For all lessons, the participants provided the research questions, but let pupils be involved in part of the designing and implementing of experiments/models (i.e. components 1.3a, 1.3b, 2.1, 2.2), and/or stimulated pupils to predict, interpret, and/or discuss the experimentation/modelling results (components 1.4, 3.3, 3.4). These lesson plans aimed for pupils replicating inquiry rather than doing authentic inquiry (there was freedom for them to do otherwise). However, these ICT in IBSE lesson plans were of good quality and suitable for teaching conditions and pupils in the Dutch schools.

Recommendations. The inquiry specifications in the activities were not completely aligned with the inquiry objectives of the lesson, and this inconsistency occurred in most lesson plans not only in Cycle 3 but also in Cycles 1 and 2. This led us to the deduction that the participants probably did not check the matches between learning objectives and activity specification and/or did not find stating learning objectives important. Therefore, for future optimisation of the course, we would add to Form 2 for the lesson plan a reminder: the
participants have to state inquiry goals explicitly and ensure consistency between these inquiry goals and the operationalised inquiry opportunities. We would also highlight this requirement in Session 1. If the participants follow this requirement carefully, they will improve the lesson plan themselves before consulting the course instructor about it. The course instructor should also consider this reminder while commenting the lesson plan.

Considering inquiry components that were intended by the majority of the lesson plans, we recognised inquiry patterns, which were similar to that of the Coach exemplary activities. These exemplary activities were primarily designed:

- for pupils to work with Coach on their own in conducting experiments or implementing dynamical models;
- for the teacher to use in interactive demonstrations.

This showed positive influences of the Coach exemplary activities on the participants in designing an ICT in IBSE lesson. However, the participants could have designed lessons aiming at inquiry goals that are more open (e.g. pupils formulating a question/hypothesis, deciding experimentation/modelling techniques, working according to own design). Therefore, for future optimisation of the course, we would:

- keep the guided-inquiry instruction of the Coach exemplary experiment/model
- design second and even third versions of text instructions that suggested the participants different inquiry patterns to use the Coach exemplary experiment/model.

b) Could the participants implement inquiry opportunities with the ICT tool faithfully in the classroom try-out?

Methods. In order to trace the implementation of operationalised inquiry opportunities from the lesson plan to the actual lesson, we examined whether or not in the classroom try-out:

- each operationalised inquiry opportunity was actually offered to pupils;
- the majority of pupils were engaged in the offered inquiry opportunity.

To examine these two aspects, using the inquiry-analysis inventory, we analysed our observation notes and videos of the try-out as well as the participant’s self-evaluation report along with pupils’ filled worksheets, Coach result files, and reports. Through this analysis, we also recorded reasons behind possible deviations from the intended inquiry opportunities in the actual inquiry activities.

Results. Of 71 inquiry opportunities operationalised in the nine lesson plans, 41 opportunities (58%) were realised in the classroom (Table 4.15) as the majority of pupils took such opportunities to exercise inquiry practices. The two following cases illustrate the engagement of most pupils in offered inquiry opportunities:

Try-out 1 (Table 4.15). Following the given worksheet (Figure 4.11), all four groups of 2 or 3 pupils could manipulate the Coach software by themselves to carry out the experiment (i.e. component 2.1); measuring and recording the resonance frequency, the height and mass of water (i.e. components 2.2 and 2.3) (Figure 4.17a). After that, for the laboratory report, the pupils decided on their own what graphs to make, then plotted these graphs and inferred the relationship between the measured variables (Figure 4.17b).
Figure 4.17. A photograph showing that pupils were measuring the height of water in a cup (a) and a scan of part of these pupils’ laboratory report in which they plotted the graph of the resonance frequency vs. the height of water and inferred a relationship between these two variables (b).

**Try-out 5** (Table 4.15). In plenary, the teacher introduced a complete Coach model of dissolving HCl by explaining the chemistry phenomenon and concepts and clarifying the modelling variables, constants, and relations. Next, she asked pupils to predict [H+] and pH vs. time graphs with different initial amounts of HCl. Of total 8 groups of 2 pupils, 7 groups sketched the graphs on the paper (Figure 4.18a), and 5 of these 7 groups could explain their predictions to the teacher (i.e. **component 1.4**). After that, based on the text instructions in the Coach activity, all groups could change the initial value of HCl-amount variable (Figure 4.18b) and then execute the model to get the modelling graphs (i.e. **component 2.1**). The pupils later on compared these graphs with their sketches and explained the changes of [H+] and pH over time during dissolution of HCl (i.e. **components 3.4 and 3.5**).

Figure 4.18. A scan of a pupil’s sketch of [H+] and pH vs. time graphs as his predictions regarding different initial amounts of HCl (a) and a photograph showing that this pupil was changing the initial value of HCl-amount variable in the given model (b).
Chapter 4

*Table 4.15.* Number of inquiry opportunities, which were operationalised in each of nine lesson plans (of the Dutch participants) in Cycle 3, which were actually offered to pupils in the try-out, and/or in which the majority of pupils were engaged.

<table>
<thead>
<tr>
<th>Try-out*</th>
<th>Number of inquiry opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>which were operationalised in the lesson plan (Stage 2)</td>
</tr>
<tr>
<td>Try-out 1</td>
<td>7</td>
</tr>
<tr>
<td>Try-out 2</td>
<td>9</td>
</tr>
<tr>
<td>Try-out 3</td>
<td>12</td>
</tr>
<tr>
<td>Try-out 4</td>
<td>7</td>
</tr>
<tr>
<td>Try-out 5</td>
<td>8</td>
</tr>
<tr>
<td>Try-out 6</td>
<td>9</td>
</tr>
<tr>
<td>Try-out 7</td>
<td>9</td>
</tr>
<tr>
<td>Try-out 8</td>
<td>6</td>
</tr>
<tr>
<td>Try-out 9</td>
<td>4</td>
</tr>
<tr>
<td>SUM</td>
<td>71</td>
</tr>
</tbody>
</table>

(*) The order of try-outs was consistent with the order of lesson plans in Table 4.14.

Of total 71 inquiry opportunities operationalised in nine lesson plans, 16 opportunities (21%) were not provided to pupils in the try-out (Table 4.15). This occurred in all nine try-outs. Based on our classroom observation and the participants’ self-evaluation reports, we recorded situations in which operationalised inquiry opportunities were intentionally shortcut by the teachers right before and/or during the try-out. For example:

**Try-out 1** (Table 4.15). A participant planned to ask pupils by themselves to choose the sampling frequency as part of the experiment design (i.e. component 1.3b). However, at the beginning of the try-out, he thought this requirement might be too difficult, so he raised the issue and then led the discussion with pupils to the right setting for sampling.

Furthermore, we also recorded unintended shortcuts of inquiry opportunities. For example:

Pupils took more time to think and discuss on a certain task (e.g. sketching graphs) than the teacher expected. Pupils were frustrated with problems in working with the experiment/model, and so this part lasted longer than intended. In the plenary, the teacher forgot to mention a key point about the task, so in work groups later on the pupils did not know what to do and/or followed a wrong track. It took the teacher a while to recognise this issue and solve it by repeating the requirement and highlighting the key point. These unintended situations resulted in lack of time for inquiry opportunities that were intended at the end of the lesson such as explaining results of the experiment, discussing limitations of the experiment, proposing generalizations of the results, or formulating new questions. Additionally, there was another case in which the teacher asked a question (e.g. what variables can we measure?) of which the answer could be easily inferred from the presentation slide or the worksheet (i.e. prepared data graph).

Of total 55 inquiry opportunities actually offered in nine try-outs, 14 opportunities (25%) were not engaged in by the majority of pupils (Table 4.15). This occurred in 7 out of 9 try-outs in which the participant was not successful in engaging more than half of pupils in particular inquiry task because it was too demanding and/or not interesting for pupils. Here was a particular situation:
Try-out 6 (Table 4.15). The teacher spent first 30 minutes of the one-hour try-out to introduce pupils to Coach modelling by explaining the modelling cycle and possibilities along with demonstrating eight Coach modelling activities. Then, he asked pupils to choose one of these activities to get acquainted with the modelling software, and then take the main assignment: modifying a given Coach model of chemical equilibrium (Figure 4.19a). With this assignment, he provided pupils with opportunities to exercise the following inquiry components: 1.3a, 1.3b, 2.5 (partly designing a model and working according to their own design), 2.1 (manipulating the software to modify the model), 3.6 (discussing limitations of the model). This conclusion is based on evidence provided in the vignette plus additional data from the lesson plan and the classroom video and observation. The assignment turned out to be too demanding for pupils regarding both cognitive load and time constraint (i.e. 20 minutes). It required basic manipulation skills (e.g. adding new variables, making connections, entering formulas with correct syntax), whereas the pupils were not at all familiar with modelling, and the teacher did not provide any technical instructions in the worksheet. As a result, all pupils were frustrated in their work groups, then waited for the teacher’s help, but just got little support, because the teacher was too busy moving around and reacting questions of different groups. Of 10 groups, 7 groups gave up the task after five minutes, and then clicked on the model meaninglessly (Figure 4.19b) until the end of the lesson. Three other groups were interested in the task and kept asking the teacher for help. With direct support of the teacher, these groups could progress, but eventually getting unexpected graphs and having no time to improve. For this try-out, just a minority of pupils could be considered as being engaged in the inquiry opportunities provided.

![Chemical modelling with Coach](a)

![Chemical modelling with Coach](b)

**Figure 4.19.** Part of a worksheet assigning pupils to modify a Coach model (a) and a photograph of a computer screen illustrating meaningless manipulations with the given model (b).

**Discussion.** The Cycle-3 participants could realise about half of total number of inquiry opportunities operationalised in their lesson plans. The other half was not offered by the teacher and/or not engaged in by a majority of the pupils. Although we let the participants make their own choices for the try-out that best fit their teaching conditions, and we limited the number of inquiry components on which each try-out should focus, they still encountered problems of realising inquiry intentions in the classroom. The participants who prepared the lesson plans thoroughly could implement inquiry intentions more faithfully than those who proposed the plan in hurry. However, it is not surprising that the participants as student teachers still had problems with classroom implementation, including cognitive-load problems and classroom-management problems. They still have to grow in matters like understanding pupils’ prior knowledge, defining suitable learning objectives, interacting with
pupils effectively, and managing time properly. The student teachers have to reinvent this type of practical knowledge for themselves in their teaching situations.

The number of inquiry components (Mean=5, SD=2) in which the participants could engage pupils in the try-out was actually less than that of components intended in the lesson plans (Mean=8, SD=2). There are several arguments involved this outcome. In particular, 1) the participants should have prepared for the classroom try-out more thoroughly; 2) they should have more experience of implementing an ICT in IBSE lesson; 3) they should have reduced their ambition and the cognitive load by limiting the number of inquiry skills intended in the lesson plans. We would like to support the third argument because of pragmatic reasons: the participants as student teachers had little experience of ICT in IBSE teaching, and the preparation time was constraint. The participants should be selective about which and how many inquiry components (about 3 to 7 components) they would intend for pupils to exercise within the lesson. In addition to a limited number of inquiry skills to aim for, what counted for cognitive load problems of both the participants and their pupils were inquiry components that were new or difficult for pupils (e.g. Try-out 6, Figure 4.19).

**Recommendations.** According to our records about classroom try-outs across the three cycles, Dutch pupils, in general, were not familiar with modelling and modelling software, although modelling has become integral part of secondary physics/chemistry curricula. Successful try-outs with Coach modelling (e.g. Try-out 7, Figure 4.14 and Try-out 5, Figure 4.18) show that it is possible to introduce pupils to modelling and the Coach modelling environment in regular lessons along with other concepts and inquiry goals (van Buuren, 2014). Based on these successful try-outs, we recommend Dutch teachers the following approaches for teaching modelling:

- Interactive demonstrations with modelling activities and minds-on discussions on concepts and phenomena (Figure 4.14)
- Pupils working in groups using a complete model to Predict, Observe, Explain (POE strategy) physics/chemistry phenomena and procedures (Figure 4.18)

Within a lesson, it is impossible to expect pupils with no experience with modelling to be able to improve a given model to better-fit reality, considering the unsuccessful try-out described above (see Try-out 6, Figure 4.19). Pupils without Coach experience can still generate suggestions for improving a conceptual model (see Try-out 7, Figure 4.14). However, if teachers aim pupils to modify or develop actual dynamical physics/chemistry models, they are advised to prepare pupils with prerequisite knowledge and skills with dynamical modelling and the modelling software perhaps through series of live sessions and/or home assignments with Coach tutorial activities. Recently, a learning path to achieve these modelling knowledge and skills has been developed for the Dutch lower secondary physics curriculum. This learning path is completely integrated into the curriculum and has been tested in school practice (van Buuren, 2014).

c) Could the participants self-evaluate implementation of inquiry opportunities with the ICT tool in their try-out?

**Methods.** In the self-evaluation report (Form 3), the participants were required to:

1. evaluate the achievement of objectives of the lesson (incl. inquiry goals);
2. indicate what did not go as intended and reasons for deviations (with evidence);
3. suggest changes of the lesson plan for future implementation in another class.

In two groups of 4 or 5 participants plus a course instructor within Session 3, the participants reported their try-outs regarding these three aspects, using their Form-3 report. Monitoring the group discourse, the course instructor ensured these aspects to be discussed among participants. We asked the course instructor and a participant in each group to take notes of the discourse and captured video of the group discussion. We reviewed the self-evaluation reports to examine whether or not the participant clearly stated their points of evaluation on the three aspects. Next, we compared participants’ self-evaluation statements with our evaluations of the try-out, which are partly presented in Section 4.3.3b. Based on videos and notes of the group discussion, we also checked if the course instructor and fellow participants agreed with the participant’s self-evaluation points.

**Results.** Of 9 Cycle-3 participants, 5 participants described the achievement of their inquiry goals clearly in their reports and presented it in Session 3 with convincing evidence from pupils’ worksheet and/or photographs (Figure 4.20). For these participants, in addition to the relevance of intended inquiry opportunities, active engagement of their pupils contributed to the realisation of inquiry goals. Here was a particular reflection:

> “6VWO students are preparing for the final exam, so they take the lesson very seriously; moreover they are smart. Therefore, they managed to execute the Coach activity on their own, although video measurement is new for them, and my instructions are general. If I teach the lesson to my 3VWO class, I cannot achieve the result like this. I have to be more suggestive; perhaps I must write more prescriptive instructions for the Coach activity or I do demonstrations with Coach” (Try-out 3, Table 4.15)

Of the 4 other participants, one participant just stated the goal achievement without evidence; three participants showed inquiry components that were realised in the try-out, but these components had not been defined explicitly in their lesson plans.

![Figure 4.20](image-url). Photographs of Cycle-3 participants presenting the achievement of inquiry goals in their try-outs with evidence: a) pupils’ poster with post-its showing that they defined variables of the model of realistic Baumgartner’s fall in air of increasing density (Try-out 7, Table 4.15) and b) a classroom photograph showing that a pupil sketched y vs. t graph as his group’s prediction about the fall of a shuttlecock (Try-out 2, Table 4.15).

All 9 Cycle-3 participants pointed out what did not go as intended in their try-outs. According to the evaluations based on our own classroom observations, there were, however,
more deviations than those reported by the participants. The participants agreed with additional points about deviations that we pointed out. Of 9 Cycle-3 participants, 7 participants explained shortcuts of inquiry intentions in their reports and/or in the group discussion. Following is a particular self-evaluation and explanation from a Form-3 report:

“With respect to the 5 action items, I had formulated to make sure the lesson was minds-on, I think the first four actions went as intended, even though the 4th item (interpreting the models and drawing conclusions) was heavily teacher-led due to lack of time to let students lead the exploration. For the same reason, I led the process of improvement of the models rather than asking students what they thought should be adjusted (from one model to the next) in order for the models to better fit the measurements (item 5).” (Try-out 7, Table 4.15)

Regarding changes of the lesson plan for different classes, four Cycle-3 participants would keep the lesson plan as it was if the number of pupils, the timeframe, the grade level, and pupils’ experience with the ICT tool were similar to those of the try-out. Four participants planned to try out with fewer pupils (i.e. two or three groups of 2 or 3 pupils) so that they could discuss properly with pupils and really engage them in intended inquiry opportunities. Five participants would like to try out in more time in order for pupils to achieve more inquiry goals as illustrated in the following report:

“Above all I would like to:

• schedule at least 2 hours for the activity so that phases 3 and 4 (execution and investigation) can be more student-led. Let students themselves think of reason and investigate how to improve the density profile of the atmosphere step by step.
• let students program their own models with Coach. This would likely require 3 hours (3 lessons) to complete the whole project.” (Try-out 7, Table 4.15)

Five participants suggested revisions of the lesson plan even if the try-out condition remained the same. Here was a particular suggestion:

“I was in doubt like to what level should I instruct students how to use Coach? I did not want to guide: click this and then click that. So I made it general. Pupils then could track data; they knew what graphs they needed; but they did not know how to choose a variable for each axis with Coach. Moreover, because tracking too many points is boring and takes time, I set the manual tracking of every 5 frames. After students did straight differentiation of \( y-t \), they got the \( v_y-t \) graph with many spikes [because the number of data are limited] that did not make sense. Next time, I have to include the hint: “take a fit of \( y-t \) first, then take a derivative of the fit”. Moreover, I would also include “If you track an objective then \( x \) and \( y \) is collected” because the term “position” I used in the current instructions is quite vague for 2D motion. This also helps students to differentiate two components of a projectile motion” (Try-out 3, Table 4.15)

According to the group discussion, the course instructors generally agreed with the suggested revisions for the try-out with different classes and provided the participants with additional ways to improve the lesson plan.

**Discussion.** The above data lead us to the conclusion that most Cycle-3 participants were capable to self-evaluate the implementation of inquiry opportunities with the ICT tool in their try-outs. Generally, it is not easy for someone to evaluate her or his own work. The participants’ sufficient self-evaluation of their ICT in IBSE try-outs was probably because of their experience of self-evaluation on teaching practice in previous courses and the internship part of the teacher-education programme.
Conclusions

The course achieved its objective regarding participants’ ability to design, implement, and evaluate an ICT in IBSE lesson. About the ability to design, the Dutch participants operationalised about 8 (SD=2) inquiry opportunities per lesson. In most ICT in IBSE lessons, one or two inquiry skills from Categories 1.1 to 1.4 and 3.3 to 3.7 were operationalised as inquiry opportunities. This attainment matches with our expectation. However, the operationalised inquiry opportunities were not completely aligned with the inquiry goals of the lesson.

Table 4.14. About the ability to implement, in the classroom try-out the participants could realise 41 out of 71 inquiry opportunities (58%), which were operationalised in their lesson plans. This attainment matches with our expectation, too. The other 30 opportunities were shortcut because they turned out to be too demanding for pupils or too ambitious for the lesson time. Importantly, most participants could recognise the deviations and problems regarding their try-outs and figure out revisions for the lesson plan to be implemented better later on in another class (the ability to self-evaluate). This achievement of the ICT in IBSE objective resulted from the sufficient operationalization of “one theory-practice cycle” principle in Cycle 3 and the relevant use of the Coach exemplary activities.

4.3.4 About participants’ motivation to study the ICT tools further and to try out more ICT in IBSE lessons

To arrive at the conclusion about participants’ motivation to study the ICT tools further and to try out more ICT in IBSE lessons, we collected evidence related to the following aspects:

a) Did the participants devise plans to apply the ICT tools right after the course?
b) Did the participants actually continue to practice the ICT tools and try out more ICT in IBSE lessons in one to two years after the course?
c) Did the participants still appreciate effects of the ICT in IBSE course as part of their teacher-education programme after getting one to two more years of teaching experience?

a) Did the participants devise plans to apply the ICT tools right after the course?

Methods. Via an open-ended question in the post-course questionnaire, we asked the participants about their plans to apply the ICT tools in their teaching in the near future. After that, we analysed each participant’s response and defined whether the participant devised plans to apply the tool after the course. We also categorised if the individual participants’ plan was general or particular. A general plan just showed the enthusiasm to apply the ICT tools and/or which tool to be applied, whereas a particular plan should clarify in more detail when, how, at which grade level, and/or why to use a specific tool.

Results. Of 33 participants across the three cycles, 29 participants (88%) reacted to this question. Of all 29 respondents, 27 participants (incl. 8 out of 8 in Cycle 3) devised plans to apply the ICT tools after the course (Table 4.16). Of these participants, 19 participants (incl. 5 out of 8 in Cycle 3) indicated general ideas, which showed their willingness of applying the ICT tools. For example:

• “I will use Coach more often for modelling, video measurement and data logging. At the moment, the use of Coach is very limited at my school.”
• “Certainly intending to do much more with Coach. I am confident to learn the necessary skills by myself and will take a course if I become too lazy to do the research myself.”
• “Investigate the possible use of VinciLab [newly developed data-logger, using Coach software], or alternatives, on a MacBook.”

Meanwhile, 8 others (incl. 3 out of 8 in Cycle 3) reported more specific plans for their use of the ICT tools in the near future. Here were two of these particular plans:

• "Actively wanting to learn to use Coach, since most teachers I’ve met (if not all) seemed to be so negative about it. I wanted to learn how to give students the opportunity to practical work beyond the (often very boring, uninteresting and far removed from their daily life and experience) classical laboratory experiments that have been done through the years and that mostly populate the text books, physics websites and experiments’ databases.”

• “I myself now can use Coach easily for data logging. I like to be able to see graphs of the previously executed experiments without Coach. I am pushing the science department into introducing the students to Coach in the beginning of year 4, so I can use the acquired skills in the years after. When I need to learn more about Coach, I will use the help function in Coach or the CMA website.”

Table 4.16. Number of Dutch participants who devised particular or general plans to apply the ICT tools after the course or had no plans at all.

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1 (N=12)</th>
<th>Cycle 2 (N=12)</th>
<th>Cycle 3 (N=9)</th>
<th>All cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>11</td>
<td>10</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Devising plans to apply the ICT tools</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>• General plans</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>• Particular plans</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Having no plans</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Discussion. Already in Cycle 1 as well as in the two subsequent cycles, almost all participants devised plans to apply the ICT tools right after the course, although their teaching conditions were not favourable yet (see also Section 4.1.2). Especially, a considerable number of participants reported specific, ambitious plans of what they would do to get over obstacles to learn and apply the ICT tools further in their classrooms. Additionally, the majority of the participants (N=32) reported that they were confident (i.e. moderately: 31%, very: 44%, extremely: 13%) to study by themselves the tools in which they did not specialise during the course (Table 4.9). All this evidence indeed showed high motivation of the participants after the course across the three cycles.

b) Did the participants continue to practice the ICT tools and try out more ICT in IBSE lessons in one to two years after the course?

Methods. One year after Cycle 3, we sent an invitation email for the follow-up questionnaire to all 33 participants. Four participants reacted that they were not teaching, so declined our invitation; 15 participants answered that they were willing to respond to the questionnaire; 14 others did not reply. We checked and realised that these 14 participants used the university mailbox when attending the course, and they might not use it at all after graduation. Therefore, we asked the teacher educators about these 14 participants’ personal or school email addresses or phone numbers and then obtained the extra contact information for 10 participants (out of the 14). After that, we emailed and phoned these 10 participants and
then got the current email of seven participants. Eventually, we collected responses to the follow-up questionnaire from 22 participants (7 out of 12 in Cycle 1, 7 out of 12 in Cycle 2, and 8 out of 9 in Cycle 3). Of 22 respondents, 21 participants (95%) already became licensed teachers; 9 participants (41%) continued to teach at the school where they did the internship, whereas 12 participants (54%) switched to another school. The follow-up questionnaire was one year after the course for Cycle-3 participants; one and a half years after the course for Cycle-2 participants; two years after the course for Cycle-1 participants. Via this questionnaire, we asked the participants three questions in order to collect data about the following aspects:

• Did the participants actually continue to practice the ICT tools in one to two years after the course?
• Did the participants actually teach more ICT and/or IBSE lessons in one to two years after the course? How often? Was it more often than before course?
• How was the participants’ motivation regarding ICT and/or IBSE one to two years after the course?

Questions and results.

Question 1 (multiple choice): “Possible to tick more than one box: after the ICT in IBSE course, have you spent time to learn more about Coach and/or similar tools?”

☐ Yes, I have learnt more about Coach tools, which I tried out with pupils during the course.
☐ Yes, I have learnt more about the ICT tools, which I did not select to try out with pupils during the course.
☐ Yes, I have learnt more about ICT tools, which are similar to Coach.
☐ No, I have not at all learnt more about either Coach or similar tools.”

Results. Of 21 respondents to this question, 13 participants (62%) actually learnt more about the ICT tools. In particular, 8 participants (38%) further developed their knowledge about the tool in which they tried out with pupils during the course; 5 participants (24% of N=21) studied the tools similar to Coach. Especially, 8 participants (38%) were able to study the tools in which they did not specialise during the course.

Question 2 (multiple textboxes): “Please fill the following blanks (...) with numbers: after the course, how often do you apply inquiry-based teaching and/or ICT (i.e. Coach or similar tools) in your lessons? (If you have not yet applied, please fill 0 in the blank)

1. I teach about…lessons per year in inquiry ways without ICT tools.
2. I teach about…lessons per year with the ICT tools but not in inquiry ways.
3. I teach about…lessons per year with integration of the ICT tools into inquiry-based activities.”

Results. About Item 1, 16 out of 21 respondents (76%) taught inquiry-based lessons but not using the ICT tools. On average, they taught about 15 lessons per year (SD=12). About Item 2, of 20 respondents, 15 participants (75%) taught lessons with the ICT tools but not in inquiry ways; about 12 lessons per year (SD = 11). Regarding Item 3, 14 out of 21 respondents (67%) taught new ICT in IBSE lessons after the course; about 11 lessons per year (SD=8).
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Question 3 (rating scale). We asked the participants if they agreed with the given eight statements regarding their ICT and IBSE teaching after the course (Table 4.17). According to the participants’ responses, about half of the participants had taught with ICT (i.e. Coach or similar tools) more often (54% of N=22), applied inquiry-teaching methods more often (46% of N=22), and taught ICT in IBSE lessons (46% of N=22) more often than they did before the course (Table 4.17). Additionally, in one to two years after the course most participants:

- were still confident to learn to use the ICT tools on their own (86% of N=22);
- could find opportunities for effective teaching with ICT tools (62% of N=21) and/or inquiry-based learning of pupils (62% of N=21) in spite of insufficient school conditions;
- still thought that their pupils should get experience with ICT tools (86% of N=22) and inquiry-based learning (81% of N=22).

Table 4.17. Percentages of the Dutch participants who agreed with, disagreed with, or were uncertain about the statements regarding their ICT and IBSE teaching after the course.

<table>
<thead>
<tr>
<th>Statements</th>
<th>N</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>After the course, I have taught with ICT (i.e. Coach or similar tools) more often than I did before the course.</td>
<td>22</td>
<td>23%</td>
<td>23%</td>
<td>54%</td>
</tr>
<tr>
<td>After the course, I have applied inquiry-teaching methods more often than I did before the course.</td>
<td>22</td>
<td>27%</td>
<td>27%</td>
<td>46%</td>
</tr>
<tr>
<td>After the course, I have taught ICT in IBSE lessons more often than I did before the course.</td>
<td>22</td>
<td>27%</td>
<td>27%</td>
<td>46%</td>
</tr>
<tr>
<td>I think that even in insufficient conditions (referring particular aspects in Figure 4.2) I can still find opportunities for effective teaching with ICT tools.</td>
<td>21</td>
<td>5%</td>
<td>33%</td>
<td>62%</td>
</tr>
<tr>
<td>I think that even in insufficient conditions (referring particular aspects in Figure 4.2) I can still find opportunities for inquiry-based learning of pupils.</td>
<td>21</td>
<td>0%</td>
<td>38%</td>
<td>62%</td>
</tr>
<tr>
<td>I think that my pupils should get experience with ICT tools.</td>
<td>22</td>
<td>5%</td>
<td>9%</td>
<td>86%</td>
</tr>
<tr>
<td>I think that my pupils should get experience in inquiry-based learning.</td>
<td>22</td>
<td>5%</td>
<td>14%</td>
<td>81%</td>
</tr>
<tr>
<td>I am confident to learn to use Coach or similar tools on my own with the given Coach activities.</td>
<td>22</td>
<td>0%</td>
<td>14%</td>
<td>86%</td>
</tr>
</tbody>
</table>

Question 4 (multiple choice plus open comments): “Possible to tick more than one box: you will apply ICT tools and/or inquiry-based teaching more often in the next academic year if

- 1. Your teaching conditions are more sufficient.
- 2. You are more competent for teaching in regard to ICT and/or IBSE.
- 3. You feel that ICT and/or IBSE plays more important role in promoting and supporting student learning.

Possibly additional opinions of yours:... [open comment box]”

Results. Of 20 respondents, 13 participants ticked Item 1; 7 ticked Item 2; and 6 ticked Item 3. The school conditions were the most influential factor for the participants’ ICT and/or IBSE incorporation in the classroom. The following open comment shows that the participant’s current motivation of ICT and IBSE teaching was not a limiting factor:
“I haven’t ticked the last box because I already feel that ICT and IBSE promote and support student learning. I don’t need to be more persuaded! My future use of ICT and implementation of IBSE don’t depend on me being further persuaded but on the other two factors.”

The following comments about current and future use of ICT and IBSE show that the participants’ current competence was not a limiting factor either:

• “I went to the course to get to know all details about Coach. I use Coach for demo’s for Physics classes, and I try to get the kids familiar with the Coach program so that they want to use it in laboratories. I am restructuring our laboratories, we try to steer away from cookbook style into: think of a question you want to answer, play with the equipment, and measure something. I notice it is very easy to get students started with Coach, it takes me about 5 minutes of explaining, combined with some ready-made *.cma files [Coach activities].”

• “We have to reshape our “leerlijnen” [learning path], and that takes time. I would like to introduce the students to more labs with Coach already in years 2 and 3. Also, I am looking for ways to improve the material we have for these grades, so the students can study in their own pace. This way we continue the independent learning that is trained in primary school, and I can build on it in upper secondary school.”

Discussion. Evidently, the participants were motivated and able to study the ICT tools further and try out more ICT in IBSE lessons as independent teachers. They even actually studied ICT tools similar to Coach and/or Coach tools which they did not study in depth during the course. In addition to trying out more ICT in IBSE integration, the participants applied the ICT tools in non-IBSE lessons and/or taught IBSE lessons, which need no ICT support. Furthermore, the participants still appreciated the relevance of ICT and IBSE learning to their pupils and devised plans to stimulate this learning. All this evidence showed that:

• the participants’ high motivation right after the course was retained after a relatively long time (i.e. one to two years).

• the participants were able to transfer their experience of learning one tool in depth within the course to learning other tools after the course.

In fact, for an individual teacher, teaching 10 to 15 ICT and/or IBSE lessons per year (about 1.5% of the total number) was not often. This resulted from unfavourable conditions (e.g. curriculum time, teacher preparation time, ICT facilities) as the participants reported. However, compared to before the course, this frequency of ICT and IBSE teaching had been improved. This showed positive effects of the course on the participants, considering the fact that they were still in first years of teaching and there were still many obstacles for actual incorporation of ICT and IBSE in the classroom. Meanwhile, there was no external encouragement such as “course assignments” and no direct support from the course instructor during this period. To conclude, the course was successful in building confidence in the participants and in preparing them for teaching ICT and IBSE lessons under realistic school conditions.

c) Did the participants still appreciate effects of the ICT in IBSE course as part of their teacher-education programme after getting one to two more years of teaching experience?

Methods. Via the follow-up questionnaire, we asked the participants the following open-ended questions:
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• Question 5: “Was it relevant to include the course in your teacher-education programme? Should the duration have been longer or shorter? Please explain.”

• Question 6: “What did you miss in the course? What should we have done differently within the course to prepare you better for teaching with ICT tools and/or for teaching inquiry-based activities?”

• Question 7: “Do you now desire further training in ICT tools and/or inquiry-based teaching? Please explain.”

Results. Of 22 respondents to Question 5, 100% evaluated that the course was relevant to be included in the teacher-education programme. Here was a particular evaluation of a Cycle-3 participant:

“Very relevant, I am happy that the course was offered and that I took it. In the teacher-education programme, we learn a lot of theory but for the implementation of it, I feel rather on my own, with very little guidance. The ICT in IBSE course was very hands-on (though the theory was also presented), gave me the opportunity to learn with and from others (knowledgeable, friendly experts and other (beginning) teachers). I got the guidance I needed to develop an activity and implement it, and the feedback after completion. The duration was fine. I strongly advise the training to other student teachers”

About half of the respondents still thought that the course outcomes met their expectations and needs for their teaching, so suggested to keep the course as it was in general (48% of N=21) (Question 6) and keep the duration in particular (68% of N=22) (Question 5).

Of 22 respondents to Question 5, 7 participants (incl. 6 in Cycles 1 and 2) (32%) thought that the course should have been a bit longer and explained, for example, as follows:

• “We now had to choose between topics, I wanted to do them all.”
• “Implementation of ICT in common curricula is quite a challenge. With a longer course maybe a greater project [the ICT in IBSE try-out] can be achieved.”
• “Longer, because I need more time to learn it and at the same time we have to do a lot of another assignments”
• “More time for "homework" and more meetings too, so that we don't just do that one assignment in our classes but actually try to integrate it into the lessons more often.”

Of 21 respondents to Question 6, 11 participants (52%) shared what they missed, so suggested changes. These suggestions reflected participants’ interests in ICT part (6 out of 11) or IBSE part (5 out of 11) of the course, and so according to them, more time and/or more focus should be required for such parts. For example:

• “More time should be taken to get familiar with the features of Coach before developing your own lesson activity.”
• “Longer timeframe to allow teachers to find appropriate lessons on which ICT and inquiry have more effect.”
• “More tips on how to deal with insufficient conditions. How could you make it so that you can convince others (colleagues, bosses etc.) to change these conditions for you?”
• “More exercises/examples of how to adapt existing activities to be more inquiry-based.”

Of 22 respondents to Question 7, 8 participants (36%) desire further training through which they could discuss IBSE teaching experience (5 out of 8) and/or study advanced ICT skills (4 out of 8). Here were particular responses:
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- "Yes, I would like to re-sync my practice with the IBSE theory."
- "After the course, I feel I was at beginners' level. I would like a further "instalments" in inquiry-based teaching to expand my repertoire and more advanced ICT skills to make me feel more confident in adapting existing Coach activities and developing new ones."
- "I find ICT in IBSE in many respects extremely appealing and with more potential overall benefits for students than more classical teaching strategies. However, preparing such ICT in IBSE lessons from scratch can be very time-demanding and very daunting. I feel I need more guidance and available materials to be able to do it successfully on a sustained timescale and not just as an one-off project."

Of 14 others who did not need further training on ICT and/or IBSE, 8 participants explained that they could study these knowledge and skills by themselves if needed. Five participants desired to focus first on general teaching skills at the moment, and four participants gave the reason regarding lack of time for coursework. Here were particular responses:

- Not in near future. I feel that I know what I need to know. I'm focusing on becoming better in general teaching skills.
- More training is always good, but I need more experience first. I am too busy developing my teaching skills on more general things.
- No. I feel sufficiently competent. I'll figure it out on my own if I feel the need. I just need time and inspiration, not training.
- No, I think I am able to find out how most tools can be used. For example, I am now using tools compatible with the iPad. But still I use the knowledge from the course to develop ICT in IBSE activities.

Discussion. Results from the three questions were consistent and together supported the conclusion that after getting one to two more years of teaching experience, the participants still appreciated the relevance of the ICT in IBSE course as part of their teacher-education programme. Although each participant took different benefits from the course, almost all of them remained motivated and confident in studying the ICT tools on their own and teaching the ICT in IBSE lessons. In order to incorporate ICT and IBSE more often in the lessons, the participants did not need to be convinced more about the important role of ICT and IBSE, but they needed more time (i.e. both curriculum time and teacher preparation time) to learn ICT in IBSE and try out by themselves.

d) Conclusions

The course achieved its motivation objective to a large extent in all of the three cycles. Right after the course, the participants were highly motivated to study the ICT tools further and to try out more ICT in IBSE lessons. This motivation was retained after a relatively long time (i.e. one to two years) and showed up in different ways:

- The participants tried out more ICT in IBSE lessons after the course and more often than before the course.
- The participants were able to transfer their experience of learning one tool in depth within the course to learning other tools after the course.
- The participants were still confident in learning the ICT tools by themselves and were able to deal with insufficient conditions for ICT and IBSE teaching.

These attainments were beyond our expectation and proved long-term effects of the “one theory-practice cycle”, “depth-first”, and “ownership of learning” principles in the Dutch
context. The participants appreciated these effects on their professional development and considered the course as a relevant part of their teacher-education programme.

4.4 Robustness test

After Cycle 3, we implemented and evaluated the fourth ICT in IBSE course in the regular context of a normal teacher education course. This Cycle-4 course was not considered as part of the optimisation of the course. Rather, it was to test:

- Were the pedagogical principles still valid in the Dutch regular context?
- Did the positive outcomes in Cycle 3 still show up in Cycle 4 without the extra inputs of the researcher?
- Could the coordination activities of the researcher be safely transferred to the course instructor in Cycle 4?

In this section, we summarise methods, report data, and draw conclusions on the robustness of the course.

4.4.1 Set-up and methods

In Cycle 4, we got seven student teachers involved in the course, and this group of participants had similar characteristics as those in Cycles 1, 2, and 3. For example, most participants were in their first years teaching, and about a half were fresh master graduates (Table 4.1). The course scenario, the support materials, the online support, and the evaluation methods in Cycle 4 remained the same as those in Cycle 3 (Table 4.12), except that the course was now taught without the extra support of the researcher.

In particular, the coordination role of the researcher was shifted to the course instructor. In order to coordinate the course in Cycle 4, the course instructor referred to a To-do list (see Appendix F). This list was based on the experience of the researcher in coordinating the course in Cycles 1, 2, and 3. Additionally, the participants had to videotape the try-out by themselves and write a more extensive self-evaluation report (Form 3), instead of having the researcher observing and recording the classroom activities. The most influential input of the researcher in Cycles 1, 2, and 3 may have been his extensive e-mail contact with participants for the classroom observation. This stimulated the participants to prepare the ICT in IBSE try-out seriously. In Cycle 4, the researcher was only involved in live sessions for observations, and the course instructor did not track participants’ preparation progress for the ICT in IBSE try-out. Moreover, unlike participants in Cycles 1, 2, and 3, the participants in Cycle 4 were tested on their knowledge and skills regarding their chosen ICT tool by the computer performance test (see Chapter 3, Section 3.3.4). In the following sub-section, we highlight main results of Cycle 4 in comparison with those of Cycle 3.

4.4.2 Results

According to our observation, live activities were implemented as intended. All 5 participants (out of 7), who responded to the questionnaire item about the course scenario, preferred the distributed scenario to the massed setting. Like in Cycle 3, the participants in Cycle 4 made use of the support materials and evaluated these materials as moderately to very useful (3.0 to 4.3 of the 5-point scale, Table 4.18).
Table 4.18. Cycle-4 participants’ evaluations of the usefulness of each material (5-point scale, 1 = not at all useful, 5 = extremely useful) in comparison with those of Cycle-3 participants.

<table>
<thead>
<tr>
<th>Support materials</th>
<th>Participants’ evaluation on usefulness of the material - Weighted average (SD)</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory slides</td>
<td></td>
<td>3.3 (0.8)</td>
<td>3.0 (0.8)</td>
</tr>
<tr>
<td>Coach introductory activities</td>
<td></td>
<td>3.9 (0.6)</td>
<td>3.8 (0.8)</td>
</tr>
<tr>
<td>Coach tutorial activities</td>
<td></td>
<td>4.5 (0.5)</td>
<td>4.0 (0.7)</td>
</tr>
<tr>
<td>Coach exemplary activities</td>
<td></td>
<td>4.3 (0.5)</td>
<td>4.3 (0.5)</td>
</tr>
<tr>
<td>Forms for planning/self-evaluating the ICT in IBSE lesson</td>
<td></td>
<td>3.3 (0.7)</td>
<td>3.2 (0.8)</td>
</tr>
</tbody>
</table>

In Cycle 4, all seven participants followed the one-tool specialisation and completed one theory-practice cycle. Of 7 participants, 4 participants completed the Coach activity for the lesson plan within Session 2; 6 participants tried out their lesson plans before Session 3 as expected; and 5 participants could develop their own, new Coach activities (Table 4.19). Regarding the computer test, 5 out of 7 participants successfully fixed the incomplete or problematic Coach activities. The two others were not successful, but they were able to demonstrate their basic manipulations during the test and in the submitted Coach result files.

Table 4.19. Number of Cycle-4 participants, who completed the Coach activity and the classroom try-out in comparison with Cycle-3 participants.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 3 (N=9)</th>
<th>Cycle 4 (N=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>who completed the Coach activity</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>• within Session 2*</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>• between Sessions 2 &amp; 3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>who completed the classroom try-out</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>• before Session 3*</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>• after Session 3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>who</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• selected Coach activities from the Coach library</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>• modified Coach activities from the Coach library</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>• developed New Coach activities</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

(*) The asterisks * indicate at which moment the Coach activity and the try-out were expected to be completed by all participants.

Of 7 participants, 6 participants submitted lesson plans and self-evaluation reports. According to the self-evaluation reports, the participants aimed at 7 (SD=2) inquiry components in the lesson plan and realised 4 (SD=2) components in the classroom. The seven inquiry components focused on in most lesson plans were 1.3a, 1.4, 2.1, 2.2, 2.3, 3.3, and 3.6. Six of these seven components were also operationalised in most lesson plans in Cycle-3 and were very relevant (Figure 4.15). Also like Cycle-3 participants, Cycle-4 participants reported their problems in implementing inquiry intentions with the ICT tool in the try-out, and they could identify the shortcomings in their ICT in IBSE try-outs. Via the post-course questionnaire, 5 respondents (out of 7) could enumerate two to three relevant benefits of the ICT tools; they showed their high confidence (3.8 of the 5-point scale, Table 4.20) in studying by themselves and applying ICT tools in which they did not specialise during the course. These five participants reported their plans to apply the ICT tools after the course.
Chapter 4

Table 4.20. Number of participants in Cycle 4 (compared with that in Cycle 3) who considered themselves “not at all”, slightly, moderately, very, or extremely confident in studying by themselves and applying ICT tools in which they did not specialise during the course.

<table>
<thead>
<tr>
<th>Number of respondents</th>
<th>Cycle 3 (N=9)</th>
<th>Cycle 4 (N=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• not at all confident</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• slightly confident</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• moderately confident</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>• very confident</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>• extremely confident</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Participants’ confidence level - Weighted average (SD)</td>
<td>3.8 (0.4)</td>
<td>3.8 (0.4)</td>
</tr>
</tbody>
</table>

4.4.3 Conclusions

The data analysis showed that the gains of Cycle 3 were sustained for the routine version of the course. The positive results of the ICT in IBSE course did not rely on the researcher’s role in coordinating the course as in Cycle 3. The robustness-test results confirmed ecological validity of the pedagogical principles. The course design and the support materials proved to be robust in the Dutch regular context. So, what the course could achieve in Cycle 3 was not a lucky result.

4.5 Final conclusions and discussion of the chapter

In this section, we draw conclusions about the effectiveness of the ICT in IBSE course and about the validity of the pedagogical principles in the Dutch context; discuss theoretical implications; and answer the first overarching question of the present research.

4.5.1 Conclusions and discussion about effectiveness of the Dutch ICT in IBSE course

a) About the awareness objective

The awareness objective: participants become aware of educational benefits of the ICT tools in science education.

The Dutch ICT in IBSE course achieved the level of the awareness objective that participants could enumerate one or two relevant benefit(s) of not only the tool in which they specialised during the course but also each of the other two tools. At the individual level, there were still several benefits not mentioned. However, considering the whole group, the participants did point out almost all benefits of the three ICT tools as discussed in Chapter 2, Section 2.1.2. The participants’ awareness of benefits of all three ICT tools probably resulted in their motivation to study the ICT tools further after the course (see Section 4.3.4). The attainment of the awareness objective matched with our expectation. It resulted from a) the sufficient operationalization of the “one theory-practice cycle” and “depth first” principles in Cycle 3 and b) the relevant use of the introductory slides and the Coach exemplary activities.
b) About the ICT mastery objective

The ICT mastery objective: participants master skills to operate the ICT tool.

The Dutch ICT in IBSE course achieved its ICT mastery objective from the adopter-user level (1 out of N=9) to the adaptor-user level (3 out of N=9) and the creator-user level (5 out of N=9). These attained levels correspond to the basic Coach skills that enabled the participants to prepare, modify, develop, and execute the Coach activity in the classroom, using their chosen tool. Considering the general case in which most teachers search ready-to-use ICT materials on the Internet and then make use or slightly modify them, the attainment of the creator-user level for 5 out of 9 Cycle-3 participants was indeed a good result of the course. These attained levels of ICT mastery were sufficient for the participants to continue practicing the ICT tools after the course on their own (see Section 4.3.4). This achievement matched with our expectation. It resulted from a) the sufficient operationalization of the “depth first” and “distributed learning” principles in Cycle 3 and b) the relevant use of the Coach introductory and tutorial activities.

The participants did not yet reach the expert level with troubleshooting skills. We did not expect them to. Remaining TCK problems of participants concerned:

- advanced features of the ICT tool,
- understanding of the phenomenon to be experimented with or modelled with the ICT tool and general experimentation/modelling skills,
- knowledge of mental model behind the digital tool that enables collection, modelling, and analysis of information about the phenomenon.

Troubleshooting skills are connected with the TCK problem. In order to achieve a good level of troubleshooting skills, participants need more experiences after the course concerning facing problems and trying out solutions. The performance computer test helps teachers to become aware of what they have to think about while facing problems (see Section 4.3.2). After trying to solve the test problems with the reasonable level of complexity and discussing solutions with the course instructor afterwards, the participants are more encouraged and more creative in troubleshooting.

c) About the ICT in IBSE objective

The ICT in IBSE objective: participants can design, implement, and evaluate an ICT in IBSE lesson.

The course achieved its objective regarding participants’ ability to design, implement, and evaluate an ICT in IBSE lesson as expected. This achievement resulted from the sufficient operationalization of “one theory-practice cycle” principle in Cycle 3 and the relevant use of the Coach exemplary activities.

About the ability to design, the Dutch participants operationalised about 8 (SD=2) inquiry opportunities per lesson. However, the operationalised inquiry opportunities were not completely aligned with the inquiry goals of the lesson (Table 4.14). Actually, this is not only a problem with the student teachers. Even curriculum developers of the 1960s, 70s, and textbook authors of the 1990s had problems...
with this as shown in Tamir and Lunetta (1981) and Germann, Haskins, and Auls (1996). This was also the case for experienced teachers in the UK, a country that has emphasised inquiry for decades, as shown in Abrahams & Millar (2008) and Abrahams & Reiss (2012). This is a persistent problem, and so indeed, student teachers must be aware in their first ICT in IBSE try-outs that they have to state inquiry goals explicitly and ensure consistency between these inquiry goals and the inquiry opportunities operationalised in ICT-enhanced implementation/modelling activities.

Regarding which inquiry skills were included, in most ICT in IBSE lessons one or two inquiry skills from Categories 1.1 to 1.4 and 3.3 to 3.7 were operationalised as inquiry opportunities. Research from Tamir and Lunetta (1981, p.481), based on analysis of laboratory manuals such as “PSSC Physics” and “Harvard Project Physics” (HPP), using the inquiry-analysis inventory similar to ours (the LAI), showed that seldom, if ever, are pupils asked to:

1.1. Formulate a question to be investigated; PSSC: 0% HPP 0%
1.2. Formulate an hypothesis to be tested; PSSC: 0% HPP 0%
1.3b. Design measurement procedures PSSC: 2.1% HPP 10.2%
1.4. Predict experimental results; PSSC: 14.9% HPP 8.2%
2.5. Work according to their own design; PSSC: 0% HPP 4.1%

If we compare our results of analysing the ICT in IBSE lesson plans (Figure 4.15) with those of Tamir and Lunetta (1981), we see that Category 1.1 (Formulating the question to be investigated) was also not intended in the 9 ICT in IBSE lesson plans. In 4 lesson plans (45% of N=9), the pupils were involved in formulating a hypothesis (Category 1.2). In 5 lesson plans (55% of N=9), they had to decide about aspects of the design of the experiment (Category 1.3b). Moreover, in 6 lesson plans (67% of N=9), they were asked for predictions (Category 1.4). In short, the ICT in IBSE lesson that the course participants designed was better than the laboratory activities analysed by Tamir and Lunetta (1981), concerning the inquiry aspect. The inquiry components that we list here stimulate pupils to think back and forth between the physical and theoretical worlds. To conclude, within the course context, we managed to bring the participants to the level of designing the ICT in IBSE lesson with good intentions of inquiry practices for pupils.

About the ability to implement, in the classroom try-out the participants could realise 41 out of 71 inquiry opportunities (58%), which were operationalised in their lesson plans. The remaining 30 opportunities were shortcut by the participants because they turned out to be too demanding for pupils or too ambitious for the lesson time. This deviation parallels results from the literature for experienced teachers (Hofstein & Lunetta, 2004; Abrahams & Millar, 2008), and so this present research contributes to the on-going discussion on teachers’ problems of realising inquiry intentions in the classroom. It is not surprising that the participants as student teachers still had problems with classroom implementation (incl. cognitive-load problems and classroom-management problems). They still have to grow in matters like understanding pupils’ prior knowledge; defining suitable learning objectives; providing clear but not too much guidance; interacting with pupils effectively; managing time properly; and other teaching skills. The student teachers have to reinvent this type of practical knowledge for themselves in their teaching situations. Therefore, we recommend beginning
teachers to limit the number of inquiry components operationalised in their first ICT in IBSE lessons. For such lessons to be faithfully implemented, in addition to this limitation, they should consider problems that cause cognitive overload for pupils. One of such problems involves inquiry components that are new and too difficult for pupils. Consequently, in their first ICT in IBSE lessons, beginning teachers are advised to focus on inquiry components that fit pupils’ prior experience. Through the first school years, they should gradually build up inquiry categories in their ICT in IBSE lessons. When getting sufficient experience with ICT in IBSE teaching, beginning teachers can aim at inquiry objectives that surpass the current level of performance of their pupils, as long as the pupils stay within the zone of proximal development.

Although the Dutch participants did have trouble to implement all intended inquiry opportunities, at least, they were able to identify the shortcomings in their ICT in IBSE lessons. Most participants could recognise the deviations and problems regarding their try-outs and figure out revisions for the lesson plan to be implemented better later on in another class (the ability to self-evaluate). This ability to self-evaluate was an important gain of the ICT in IBSE course compared to the literature (one-step beyond the literature).

The participants did not yet realise the ideal ICT in IBSE lesson due to limited contact hours, little preparation time within the course, and not yet favourable teaching conditions. However, they did realise quite acceptable lessons. The Dutch case study revealed a few effective patterns and pedagogical considerations of ICT in IBSE teaching in the Dutch context, especially with the Coach modelling tool (see Section 4.3.3b). The participants had learnt much thanks to the complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson in the classroom. The classroom try-out indeed enabled the participants to reflect on different practical aspects of ICT in IBSE teaching. This reflection contributed to the participants’ confidence in independent learning for ICT in IBSE inclusion in the classroom. The participants’ confidence and their ability to self-evaluate were a step-up for the Dutch participants later on to learn ICT in IBSE teaching on their own. With more teaching experience, they would probably incorporate ICT in IBSE more often than the average teachers would.

d) About the motivation objective

The motivation objective: participants are motivated to study the ICT tools further and to try out more ICT in IBSE lessons with pupils.

The Dutch course achieved its motivation objective to the highest level according to our definition: a relatively long time after the course (one to two years), the participants actually studied the ICT tools further and tried out more ICT in IBSE lessons with pupils. This showed that level of motivation with which the participants finished the course remained high over a period of one to two years after the course. Moreover, the participants were able to transfer their experience of learning one tool in depth within the course to learning other tools after the course. One to two years after the course, the participants were still confident in learning the ICT tools by themselves and were able to deal with insufficient conditions for ICT and IBSE teaching. These attainments were beyond our expectation and were long-term effects of “one theory-practice cycle”, “depth-first”, and “ownership of learning” principles in
the Dutch context. The participants appreciated these long-term effects on their professional development and evaluated the course as a relevant part of their teacher-education programme. The Dutch ICT in IBSE course was successful in building confidence in the participants and in preparing them for teaching ICT and IBSE lessons under realistic school conditions.

e) Final remark about effectiveness of the Dutch ICT in IBSE course

Generally, the Dutch student teachers achieved the course objectives, also when the course was taught under the routine conditions. This achievement in the Dutch ICT in IBSE course is a good point of departure for participants to pursue the long-term vision of the course: sustainable incorporation of ICT in IBSE in teaching practice. It is obvious that Dutch participants as student teachers after the ICT in IBSE course need several years to be stable in teaching and to be able to realise part of this long-term vision. They do not need to be convinced more about the important role of ICT and IBSE, but they need more time (i.e. both curriculum time and teacher preparation time) to master ICT tools and implement ICT in IBSE in the classroom effectively.

4.5.2 Conclusions and discussion about the pedagogical principles in the Dutch context

a) Validity of the pedagogical principles in the Dutch context

Based on the literature and the four course objectives, we defined four pedagogical principles as a theoretical model for the short ICT in IBSE course. After that, we operationalised these pedagogical principles further in the initial course scenario, considering the course objectives and the boundary conditions of the Dutch course. This operationalization of the principles, however, was not yet implemented faithfully in Cycles 1 and 2. Based on the course evaluations in Cycles 1 and 2 and the pedagogical principles, we optimised the course scenario (Cycle 3) toward the third version (Table 4.12). This optimised scenario provided sufficient practical conditions for the four pedagogical principles to be implemented faithfully in Cycle 3 (see Sections 4.2.1 to 4.2.4). Vice versa, the sufficient implementation of the four pedagogical principles in Cycle 3 resulted in the expected attainment of the four objectives of the Dutch ICT in IBSE course. In short, the pedagogical principles functioned as the cornerstones for the course design and served as guidelines for fine-tuning the course scenario to improve attainment of the course objectives. Based on this line of arguments, we conclude that the four pedagogical principles proved to be effective in the Dutch context. This conclusion was strengthened by evidence from the robustness test of the Cycle-3 course scenario in a normal teacher-education course (Cycle 4) without assistance of the researcher (see Section 4.4).

In the Dutch context, the present design research under the pedagogical principles ended up with a) the good design of the short ICT in IBSE course for Dutch student teachers and b) our findings about operationalization and implementation of pedagogical principles (what did work, what did not work, and why). The present research in the specific context and aims confirmed and added to the literature from which the four pedagogical principles stem. Therefore, these pedagogical principles became stronger and more worthwhile to be
recommended for future research and applied in educational practice. In the following sub-sections, we will discuss these findings further for each pedagogical principle.

b) Findings and implications concerning the “one theory-practice cycle” principle

The “one theory-practice cycle” principle: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson in the classroom within the course.

Although teacher-education programmes try to be “practical”, there are often complaints from student teachers that the theory and illustrated practices that they learn are relatively disconnected from their teaching practices in the school. In the induction phase, it is difficult for beginning teachers to try out innovative ideas (e.g. ICT in IBSE); they might implement such ideas in unexpected ways, and hardly have someone to provide feedback for improvement. This issue is often called the “theory-practice gap” or “theory-practice divide” in teacher education (Korthagen, 2010) and related to the tension in the first years of teaching and transition of knowledge and skills from pre-service teacher education (Beauchamp & Thomas, 2009).

The operationalization that student teachers experience one complete cycle of designing a lesson, implementing it, and evaluating the outcomes (process and product) within a teacher education course makes the “one theory-practice cycle” principle outstanding. The ICT in IBSE course was a nice example of having objectives of a teacher-education course and taking them all the way to the classroom for implementation and evaluation. This principle can contribute to solving the “theory-practice gap” problem. Following this principle, the course prepared the student teachers with both theory and school practice; the classroom try-outs were stimulated, prepared, and discussed in live sessions at the university. Importantly, the course attained the particular objective related to the theory-practice cycle (i.e. the ICT in IBSE objective). This showed particular effects of the ICT in IBSE course and further suggested the application of the “one theory-practice cycle” principle in other elements of the teacher education programme. The ICT in IBSE try-out was what the participants liked about the course, and they found the course very relevant in their teacher-education programme (see Section 4.3.4).

Guiding an IBSE activity in the classroom can be one of core practices for teacher education as Grossman, Hammerness, and McDonald (2009) proposed. Actually guiding an IBSE activity includes two of the core practices proposed by Grossman et al. (p.280-281): “eliciting pupil thinking” and “orchestrating classroom discussion”. One theory-practice cycle can be a strategy for student teachers to learn the core practice: guiding an IBSE activity. The strategy involves with a process in which student teachers “taste” what is offered in teacher education, “digest” it through the classroom try-out and follow-up discussion with the teacher educator, “grow” in PCK, and then desire to “taste” more.

c) Findings and implications concerning the distributed learning principle

The distributed learning principle: participants study in live sessions and carry out individual assignments in between the sessions with support materials and in consultation with the course instructor.
In the present research, distributed learning was operationalised in the course scenario in two ways. First, *live sessions were distributed over a long period* (e.g. 1 to 3 months) instead of forcing it in a few days. Second, we made use of the time in between live sessions for individual assignments and counted this time as part of total study time. Consequently, the Dutch ICT in IBSE course included a contact part (live sessions: 12 out of 28 hours) and a distance part (individual assignments: 16 out of 28 hours). For the ICT in IBSE course, the distance part was considered as important as the contact part with respect to the course objectives.

In our research, timing was evaluated and refined. Through two iterations of refining the Dutch course scenario, we made quite big changes in distributing the total study time across sessions versus assignments and in extending the time between sessions. Eventually, we got more faithful implementation and better outcomes of the course in Cycle 3. We recognised the following conditions for the distributed-learning scenario to be effective:

- *Basic mastery of the ICT skills* that was prepared and initiated in Session 1 and that enabled the participants to work with the ICT tool independently. Consequently, Session 1 was very intensive;
- *Sense of direction* of what the participants needed to do in between live sessions (i.e. awareness of the course scenario and objectives) (see Section 4.2.3);
- *Intensive support* for the participants while learning outside live sessions. Such support was from support materials and through the consultation with the course instructor (see Section 4.2.2).

To conclude, as far as distributed learning is concerned, allocating sufficient time for the participants to prepare and accomplish individual assignments in between live sessions is crucial. If student teachers are provided with much freedom and responsibility outside live sessions, then first intensive live sessions, sense of direction, and coaching of individual assignments need to come in.

*d) Findings and implications concerning the depth-first principle*

The depth-first principle: *participants specialise in only one ICT tool (by choice) after having been introduced to the possibilities of the three ICT tools (i.e. data logging, video measurement, and modelling).*

In the present research, the depth-first principle was operationalised as a one-tool specialisation that enabled the participants *within a short course* to reach the point of integrating the ICT tool in inquiry-based classroom activities. Importantly, depth first was not only depth. For the ICT in IBSE course, after becoming acquainted with the possibilities of all three tools, the participants specialised in only one tool with the long-term vision of learning two others after the course (breadth-later). In fact, specialisation in only one tool did not prevent participants to study the other tools after the course. Our research outcomes proved that the participants could fulfil the one-tool specialisation and were motivated and able to study other tools one to two years after the course (see Section 4.3.4).

The depth-first principle has a *surplus value* irrespective of the length of the course. *Better understanding of one tool has surplus value compared to partial understanding of all three tools.* Through specialisation in one tool, student teachers get deeper understanding and
higher mastery of the chosen tool, get a better grasp of the Coach platform as a whole, and get used to the similarity among the three Coach tools. Consequently, the step to learn other tools should be smaller than that to learn a Coach tool from scratch. Student teachers might learn other tools on their own and with less need of support. Furthermore, with better understanding, student teachers become aware of the educational benefits of the ICT tools in science education, feel confident, and gain motivation. This creates momentum for student teachers to learn other tools. In short, deeper understanding of one ICT tool leads to better transfer for the whole ICT environment.

From the perspective of teachers as designers and researchers, the course participants were provided with the constructional ICT tools. Simultaneously, they were guided explicitly in learning and applying one particular tool through the ICT in IBSE try-out. With the momentum (mastery, confidence, and motivation) gained through the one-tool specialisation, the participants studied other ICT tools and tried out more ICT in IBSE lessons after the course. High workload is what student teachers commonly complain about. One aspect of the workload pressure is that they have too much knowledge to learn within in a limited time. The depth-first approach can be applied as part of a solution for the problem of overloaded contents in teacher education. Suppose a teacher education course having ultimate objectives related to several domains; then the course instructor should give orientation on the entire area and then start deep in a domain (e.g. one component of the ICT environment, one part of the school curriculum, one out of many techniques of conceptual development). How much time for orientation on the entire area and how much time for specialisation in one domain are dependent upon the circumstance of the teacher-education course. After that, the course instructor stimulates and trusts the transfer abilities of student teachers to other domains.

*e) Findings and implications concerning the ownership of learning principle*

The ownership-of-learning principle: *participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives.*

We did achieve with the ICT in IBSE course that the student teachers did not hide themselves behind the complaint of unfavourable conditions. One to two years after the course, they continued to study the ICT tools and try out ICT in IBSE lessons. This resulted from their ownership of learning during the course. They made use of their freedom of choice (e.g. see the whole spectrum of ICT in IBSE activities in Table 4.10); tailored and pursued their own learning process; and attained demonstrable outcomes (i.e. the four course objectives). For the Dutch ICT in IBSE course, the personalised support with an explicit support framework (i.e. course scenario and support materials) worked well. One of the main revisions of the course scenario from Cycle 1 to Cycle 3 was the effective shift from plenary to individual or group activities that were directly related to the individual assignments (see Section 4.2.2). The course instructors as coaches were committed to the success of the individual student teacher in the classroom try-out. They supported the student teachers not only as a group but also individually; they kept the student teachers on task outside live sessions; and they suggested solutions for the individual student teacher’s problems in live session or via email consultation (see Section 4.2.2).
Through two iterations of refining the Dutch ICT in IBSE course, we realised that ownership of learning is a useful method to empower student teachers, and ownership of learning can only be achieved with personalised support and sense of direction.

**Empowering student teachers.** As far as the ICT in IBSE try-out is concerned, the student teachers knew best about their own teaching situations. Consequently, with the freedom of choice, they could choose a topic or activity that fitted the conditions at their school. As a result, they took initiative to develop their own activities and so became the owner of what happened in the classroom try-out. This way indeed empowered the student teachers, and they could make their own conditions more favourable. With the ownership of learning principle, heterogeneity of the Dutch participants and their realistic teaching conditions were not obstacles for faithful implementation of the ICT in IBSE course.

**Personalised support and sense of direction.** Ownership of learning and independent learning did not merely involve student teachers working alone. The teacher educator had a key role to play in stimulating and supporting ownership of learning though. Ownership was only possible when the student teachers were able to make their own decisions and pursue their self-tailored learning towards the course objectives. Such processes were diverse because of the heterogeneity of the Dutch participants and their teaching conditions. During the self-tailored process, a participant encountered her or his own specific difficulties and so needed personalised support. Considering the time-constraint condition, the personalised support must be in time in order for the participants to get over the obstacles early, maintain their motivation, continue to pursue their self-tailored learning, and accomplish the individual assignments within the intended time. In short, freedom of choice is crucial to develop ownership of learning. In order for student teachers to make use of the freedom of choice, they must be aware of the course objectives and then develop the sense of direction towards these objectives; freedom of choice requires personalised support. Therefore, personalised support and sense of direction are very necessary to establish ownership of learning. Here is a balance between much freedom of choice and appropriate guidance.

As far as the long-term vision of the ICT in IBSE course is concerned, for many countries, we can say that ICT in IBSE is not common yet in the classrooms; it is still an innovation rather than routine. One of the reasons involves perception of teachers. Many teachers believe that ICT in IBSE teaching is only possible as teaching conditions are favourable; pupils have ICT skills and are used to inquiry learning. Meanwhile, there are various patterns of inquiry teaching with ICT, which are possible in even unfavourable conditions. However, it is difficult to change the mind-set of teachers with long experience. Establishing a right mind-set about ICT in IBSE teaching to student teachers is more likely and important for their future incorporation of ICT in IBSE in their regular teaching. Therefore, we would like to suggest establishing the mind-set of dealing with insufficient conditions for ICT in IBSE incorporation in teachers during their teacher education programme. Student teachers a) select a few inquiry objectives to focus on; b) are aware that pupils' prior knowledge and school conditions might not be appropriate yet; c) decide on their own what best fit their teaching condition; d) try things out in the classroom; and e) experience what is possible in regard to ICT in IBSE teaching in the classroom.
f) Conclusion about usefulness of support materials

The support materials were developed and/or selected in order to implement pedagogical principles with respect to the course objectives. They proved to be necessary and useful for the participants to learn in the distributed scenario, to master one ICT tool in depth, to design the ICT in IBSE lesson, and to pursue their self-tailored learning process. Each type of materials played a different role in the participants’ learning process and contributed to the course objectives to large extent (see Section 4.2.5). In the present research, we did not focus on improving the materials themselves because already in Cycle 1 of the course, the participants appreciated the usefulness of such materials.

When evaluating summative effects of the course, we recognised some ideas to develop new materials and enrich the existing materials. Because these ideas came up after Cycle 3, we recommend for future optimisation of the course. In particular, during the course, the participants would encounter TCK problems regarding the Coach tool and the Coach activity. We recommend developing the following new material and instrument to support the participants more effectively. First, it is useful to develop a repository of the most common TCK problems and related solutions and upload it on the course website so that the participants can consult it (see Section 4.2.3). Second, it is useful to develop a computer performance test of whether or not the participants already gain sufficient skills with the specialised tool through Session 1 and Assignment 1. The test should be administered at the beginning of Session 2. After trying to solve the problems and discussing solutions with the course instructor afterward, the participants will be aware of what they have to think about while facing problems. The participants will become more confident and more creative in troubleshooting TCK problems, which the participants might encounter while preparing and implementing the Coach activities within the ICT in IBSE lesson (Assignment 2).

In order to support the participants more effectively in designing the ICT in IBSE lesson, we recommend enriching the two existing materials. First, Form 2 for the ICT in IBSE lesson plan should be added with a reminder: the participants have to state inquiry goals explicitly and ensure consistency between these inquiry goals and the operationalised inquiry opportunities (see Section 4.3.3). Second, the Coach exemplary activities should be enriched with second and even third versions of text instructions that suggested different inquiry patterns to use such exemplary materials (see Section 4.3.3).

4.5.3 Brief answer for the first overarching research question

The four objectives and four pedagogical principles together form the core characteristics of the ICT in IBSE course. On the way to study these characteristics, we simultaneously developed an effective scenario as an educational product. This scenario made use of the support materials, which proved to be very useful for the Dutch participants. The developed scenario (incl. the timeframe, live activities, assignments, and online support) proved to be quite optimal for the Dutch context. Figure 4.21 visualises this optimal scenario of the ICT in IBSE course (Cycle 3) which reflects:

- the specific operationalization of the pedagogical principles in the Dutch context,
- the general time-frame for the three live sessions and two assignments,
- the plans on when to use which support materials and assessment methods.
Figure 4.21. The optimal scenario of the ICT in IBSE course in the Dutch context.

For more detail about what to do in live sessions and what is required for individual assignments, see Table 4.12. For more detail about how we came to this optimal scenario see Section 4.2 about the revisions in Cycles 1 and 2. The optimal course proved to be robust and applicable to the teacher education programme in the Netherlands, regarding a) time relevance (i.e. 12 hours for three live sessions and 16 hours for assignments) and b) sensible and achievable outcomes.
Chapter 5 Adaptation, implementation, and evaluation of the Slovak ICT in IBSE course

This chapter presents the Slovak case study: the adaptation, implementation, and evaluation of the ICT in IBSE course in the Slovak context in two cycles. In Section 5.1, we summarise the aim and methodology of the case study and describe the Slovak context. Section 5.2 presents the concrete scenario of the Slovak course in Cycle 2 and the support materials. In Section 5.3, we clarify how we adapted the evaluation framework and instruments, which were described in Chapter 3. In next two sections, we present and discuss the results of the course evaluation regarding a) the implementation of the pedagogical principles and the support materials in the Slovak context (Section 5.4) and b) the effectiveness of the Slovak ICT in IBSE course (Section 5.5). In Section 5.6, we finally draw conclusions about the attainment levels of the Slovak course, the validity of the pedagogical principles, and the transferability of the ICT in IBSE course in the Slovak context.

5.1 Background, context, and methodology

In Section 5.1.1, we summarise the explorative phase of the present design research and explain why the Slovak case study was included in the cyclic research phase. Section 5.1.2 describes the Slovak context of the ICT in IBSE course. In Section 5.1.3, we clarify the expected attainment levels of the four objectives of the Slovak course, considering this local context. Finally, in Section 5.1.4 we describe how we operationalised the four pedagogical principles in the Slovak course scenario with respect to these expected attainment levels.

5.1.1 Summary of the explorative phase of the research project

In the explorative phase of the present design research, we defined a) the general design of the short ICT in IBSE course, including the four course objectives, the four pedagogical principles, and the support materials and b) the evaluation framework plus instruments for data collection and analysis (Chapters 2 and 3). In the cyclic research phase, we aimed to test validity of the pedagogical principles, effectiveness of the ICT in IBSE course (attainment of the objectives), and transferability of the general design (incl. the support materials) through case studies with different teacher groups in different countries. In addition to the Dutch case study in which we implemented, evaluated, and optimised the ICT in IBSE course for Dutch student teachers (Chapter 4), we explored testing opportunities in different educational and cultural contexts.

We had an opportunity to implement the ICT in IBSE course for Slovak teachers with diverse teaching experience and with little experience with ICT tools. The Slovak cultural and educational context is considerably different to the Dutch one. In Slovakia, there has been a curriculum reform, which emphasises on inquiry skills and ICT incorporation in science education. As a result, ICT tools are now available in Slovak schools. This circumstance is an interesting test bed, so we deliberately chose to conduct the Slovak case study. We collaborated with Slovak teacher educators to adapt, implement, evaluate, and optimise the Slovak ICT in IBSE course. The Slovak case study included two...
iterative cycles of implementing and evaluating the Slovak course, and its aim was to address two main research questions:

A. To what extent were the four pedagogical principles implemented in the Slovak context as intended?

B. To what extent did the Slovak ICT in IBSE course achieve its four objectives?

The initial scenario of the Slovak course was elaborated and adapted from the general design of the course by the Slovak course instructors and the researcher, considering characteristics of the Slovak context and boundary conditions of the Slovak course within the national accreditation system for teacher professional development (PD).

In Cycle 1, this initial scenario was implemented, and the evaluation of the course resulted in revisions of the course scenario for Cycle 2. We reported these evaluation and revisions in Jeskova, Tran, Kires, and Ellermeijer (2015b), which was co-authored by the Slovak course instructors. Since we already described a detailed optimisation process through three iterative cycles in the Dutch case study, we will limit ourselves here to answering the research questions for the final optimised scenario and the summative outcomes of Cycle 2. For more detail about Cycle 1 of the Slovak course, please refer to Jeskova et al. (2015b).

5.1.2 The Slovak context and boundary conditions of the Slovak course

a) The Slovak context

In Slovakia, there is a teacher professional development (PD) system oriented towards specialisation, modernisation, and innovation in secondary education. Schools allow teachers to take five days off per school year for PD. Teachers have many options for in-service training that is offered by universities and accredited by the Ministry of Education of the Slovak Republic. After successful completion of a course, teachers receive certificates and credits that are then reflected in a special salary bonus (Jeskova et al., 2015a). The Slovak ICT in IBSE course was adapted to fit this national accreditation system and offered by the Pavol Jozef Safarik University in Kosice. The course was open for teachers from nationwide secondary schools to enrol. Eventually, 66 Slovak teachers of science participated in one of the two cycles of the ICT in IBSE course (Table 5.1). There is no reason to suspect that this group of 66 teachers is not representative for the population of science teachers in Slovakia. Through an email to all participants and in the first live session, the Slovak course instructor explained the data-collection procedure for recording participants’ activities in live sessions and their individual assignments and then asked for their consent. All of them were willing to cooperate for the data collection.

The participants’ incentives were not only to get credits for a salary bonus but also to learn new knowledge and skills regarding the ICT tools and IBSE. Half of the participants worked at schools that took part in ICT projects (e.g. Modernization of primary and secondary education\(^1\), InfoAge project\(^2\)). These projects involved a) equipping the science laboratory with computers, additional equipment, sensors, and software and b) training teachers for sufficient ICT integration in the classroom. The teachers were required to participate in

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\(^1\) See the project website: [https://www.modernizaciavzdelavania.sk](https://www.modernizaciavzdelavania.sk)

\(^2\) See the project website: [http://www.infovek.sk/index.php](http://www.infovek.sk/index.php)
training courses like our ICT in IBSE course to learn how to handle ICT tools, how to develop appropriate instructional materials on the use of ICT, and how to teach with the tools. Moreover, since 2008 Slovakia has implemented an educational reform across all levels of primary and secondary education. This reform emphasises a shift from mainly content-based learning towards the development of inquiry skills (Mackovjakova & Jeskova, 2014). Through courses like the ICT in IBSE course, participating teachers prepare themselves for a shift towards inquiry required by the curriculum reform.

b) Characteristics of the Slovak participants

The participants of the Slovak ICT in IBSE course were teachers with diverse teaching experience, from first years to 33 years of teaching; the average experience was about 19 years of teaching (Table 5.1). In both cycles, there were many more physics teachers participating in the course than chemistry, biology, and geography.

Table 5.1. The number of Slovak teachers participating in one of the two cycles of the ICT in IBSE course and the background information.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Cycle 1 (N=39)</th>
<th>Cycle 2 (N=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching subject</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Biology</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Geography</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Not familiar with the ICT tool at all</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data logging</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Video measurement</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Modelling</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>Years of teaching experience: average (Min–Max)</td>
<td>19 years (1 to 32)</td>
<td>19.5 years (4 to 33)</td>
</tr>
<tr>
<td>Course duration</td>
<td>3/2013 to 6/2013</td>
<td>10/2014 to 02/2015</td>
</tr>
</tbody>
</table>

Generally, before the course, the Slovak participants had very little experience with ICT tools (Figure 5.1), especially dynamical modelling. A remarkable number of participants had no experience with the ICT tools. For example, in Cycle 2, 11, 14, and 18 out of 27 participants were not at all familiar with data logging, video measurement, and modelling, respectively. A few physics teachers had considerable experience with one or two particular Coach tools before the course, whereas almost all chemistry and biology teachers lacked basic knowledge about these tools. Recently, a microcomputer-based laboratory with Coach has been integrated in the curriculum of pre-service teacher education at Slovak universities (Demkanin, 2008). Therefore, participants, who just graduated from teacher education, had better ICT skills with Coach than those who graduated many years ago.

The majority of the participants had participated at some time in national conferences and/or in-service courses on IBSE, so they were aware of inquiry-based teaching and its benefits. They had tried out IBSE lessons in the classroom. However, as most participants
reported, they still lacked practical knowledge and experience and found it difficult to design and teach inquiry-based activities in the classroom.

![Figure 5.1](image)

**Figure 5.1.** Level of Slovak participants' familiarity with each Coach tool before the course (self-report via the pre-course questionnaire; 5-point scale, 1 = not at all familiar, 5 = extremely familiar).

c) **Teaching conditions of the Slovak participants**

Via the follow-up questionnaire, we asked the participants to evaluate their teaching conditions for inquiry-based teaching and application of the ICT tools. The response data show that there were considerable differences among participants' schools (see standard-deviation bars in Figure 5.2), especially about availability of computers, software, and sensors. Lack of equipment, big class size, and limited number of science lessons per week were still common complaints of teachers (Bartosovic & Demkanin, 2014). Just half of the participants had the Coach software and equipment available in their schools.

![Figure 5.2](image)

**Figure 5.2.** The Slovak participants' self-evaluations of their teaching conditions for application of ICT and IBSE in the classroom (N=44) (5-point scale, 1=poor, 5=excellent).

Among the three Coach tools, data logging with sensors and video measurement fit the implemented curriculum and were used to some extent in Slovak schools. Part of the school final exam is in oral format and includes practical work. Pupils have to present the
theory, carry out an experiment, and interpret the results orally. This requirement has stimulated laboratory demonstration and practical work in regular science teaching. These activities have enabled pupils to gain reasonable experience in using ICT tools (Figure 5.2). Additionally, science teachers are also interested in the use of dynamical modelling in science education although it was not yet an integral part of the science curriculum.

The school conditions are changing positively as in many schools of the Slovak participants the school management supports integration of ICT into experimentation activities by purchasing computers, sensors, and interfaces and financing teachers’ participation in ICT courses. School boards have allowed the division of classes (30 to 35 pupils) into two smaller groups that are suitable for experimentation activities with limited equipment and only-one teacher’s guidance. On the post-course questionnaire a Slovak participant wrote (translated from Slovak by the course instructor):

Within a national project, we got equipment for 9 ICT-enhanced laboratory packages. Up to now, in a week, we have one physics lesson with the whole class and one lesson with half a class in each of the first three grades. Within the half-class lesson, we usually do Coach experimentation activities with pupils. The way we conduct science lessons with ICT-enhanced experimentation increases the status of our school. That is why the school management supports us for ICT incorporation.

Although the national curriculum documents stipulated an orientation on inquiry skills, there were not yet official examinations on inquiry skills. The school-leaving examination and the entrance examination to university are still very fact-based and more or less the same as they were before the implementation of the reform. Old textbooks and traditional teaching methods based on transmission of knowledge are dominantly used. There are not enough IBSE teaching materials, and IBSE teaching is still rare in Slovak schools (Jeskova et al., 2015a). Consequently, Slovak teachers are in a dilemma between the demand of stimulating regular inquiry learning of pupils and optimal preparation for the traditional university entrance examinations. As a result, Slovak pupils generally lacked experience of inquiry-based learning (Figure 5.2).

d) Time constraints as boundary conditions of the Slovak course

First, the Slovak ICT in IBSE course was limited to 20 contact hours in Cycle 1 and 25 contact hours in Cycle 2. This time was rather limited, considering the requirement of bringing participants with very little ICT knowledge and skills to the level of using the ICT tools to design and teach an inquiry-based lesson.

Second, the teachers could only take days off for attending live sessions. For individual assignments between live sessions, they had to find own time in their busy teaching schedules. Although school managers find ICT and IBSE teaching useful and important, they do not invest more time for teachers to design and teach ICT and IBSE lessons. Additionally, there are no technical assistants at school; science teachers have to develop experiments, check equipment before use, and guide pupils during practical work by themselves. This entailed extra preparation time for science teachers compared to teachers of other subjects (e.g. math, history). As a result, time for individual assignments turned out to be limited.

Finally, design and try-out of ICT in IBSE lessons were possible only at the end of the course after the Slovak participants mastered basic skills with the ICT tools. Therefore, during
the 12 to 15 weeks of the course, only the last 5 to 7 weeks could be used for the try-out. Meanwhile, changes in the science curricula led to a limited number of lessons (e.g. one or two physics lessons per week, total 30 weeks per school year), whereas there were still many content-knowledge goals to attain. In short, curriculum time and opportunities for ICT in IBSE try-outs at the end of the course were anticipated to be limited.

5.1.3 Expected attainment levels of the Slovak course objectives

Taking the characteristics of the Slovak participants, their teaching conditions, and time-constraint conditions of the Slovak course into account, we adapted the expected attainment levels of the four course objectives. These objectives were described in Chapter 2 as follows:

1. Awareness objective: Participants become aware of educational benefits of the ICT tools in science education.
2. ICT mastery objective: Participants master skills to operate the ICT tool.
3. ICT in IBSE objective: Participants can design, implement, and evaluate an ICT in IBSE lesson.
4. Motivation objective: Participants are motivated to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.

In the Slovak context, the Slovak participants’ incentives were to learn different ICT tools to the level that they could a) create their own Coach activities, b) train their colleagues to handle Coach tools, and c) guide pupils to manipulate the tools in the classroom. These incentives were in line with the school demand that the participants had to make proper use of different ICT tools, which were newly added to the science laboratory. Therefore, regarding the awareness objective, we expected that after the course, the Slovak participants could enumerate one or two relevant benefits of each of the three ICT tools. About the ICT mastery objective, we expected that most Slovak participants would achieve basic Coach skills with all three ICT tools. Referring to the predefined attainment levels in Chapter 3, Section 3.4.3, we expected most Slovak participants to reach the creator-user level for the tool in which they specialised for designing and teaching the ICT in IBSE lesson. At this level, these participants should be able to develop their own Coach activities for their ICT in IBSE lessons. These attainments were crucial and challenging, considering that the entrance level of the Slovak participants regarding ICT mastery was low.

Regarding the ICT in IBSE objective, referring to the predefined attainment levels in Chapter 3, Section 3.4.3, about the ability to design, we expected to see in most lesson plans one or two inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7 to be operationalised. About the ability to implement and self-evaluate, we expected that about half of the participants would be able to realise their inquiry intentions in the classroom and self-evaluate their classroom try-outs. The expectation about just a half of participants instead of all was because implementation of an ICT in IBSE lesson was beyond the basics of science education in Slovak schools, and both the participants and their pupils generally lacked experience of inquiry-based teaching and learning.

Regarding the motivation objective, referring to the predefined attainment levels in Chapter 3, Section 3.4.3, we expected that the majority of the participants would achieve at
least Level 2: right after the course, they devised plans to learn and apply the ICT tools further. We hoped about half of the participants would achieve Level 3: relatively long time after the course (0.5 to 1.5 years), they had actually studied the ICT tools further and had tried out more ICT in IBSE lessons with pupils. Just “a half” was because teaching conditions (e.g. curriculum time, teacher preparation time, availability of ICT) in Slovak schools were not favourable yet for sustainable incorporation of ICT in IBSE.

5.1.4 Operationalization of pedagogical principles in the Slovak course

The pedagogical principles underlying the general design of the ICT in IBSE course matched quite well with the Slovak context. Consequently, we used these principles for the Slovak course and made adaptations regarding the expected attainment levels of the course objectives, scheduling requirements, and characteristics of the Slovak context. In particular, regarding the "one theory-practice cycle" principle, we assigned the Slovak participants to design an ICT in IBSE lesson plan as a formal, compulsory requirement to complete the course (i.e. the last individual assignment). Each participant had to present her or his ICT in IBSE lesson plan to a three-member committee in a formal setting, called “final defence”. We also recommended the participants to try out their ICT in IBSE lesson plan in advance and then self-evaluate this ICT in IBSE try-out in the final defence. However, we did not make the classroom try-out a mandatory requirement. Considering the lack of ICT equipment in Slovak schools, the minimum facility for the ICT in IBSE try-out would be a computer with Coach-software installed, a beamer, and/or limited equipment. In this minimum condition, the participants could carry out teacher-led demonstrations and engage pupils in designing experiments/models and interpreting the results.

The distributed-learning principle underlying the ICT in IBSE course concerned the division of the total study time (i.e. 40 hours) between live sessions (contact part) and individual assignments (distance part) between these live sessions. With this principle, we had to consider the distance part with assignments as important as the contact part and so provided the participants with support materials and online support to ensure the effectiveness of the distance part. Considering that the Slovak participants were expected to achieve the creator-user level of the ICT mastery objective, whereas their entrance was at almost non-user level (i.e. low ICT-mastery entrance level), we allocated reasonable time for live sessions (i.e. 25 out of total 40 hours). That way the participants would have sufficient time to practice basic manipulations with the ICT tools with direct support of the course instructor and each other. Moreover, the Slovak participants had to invest additional time for individual assignments (developing a Coach activity from scratch), which would reinforce and improve their skills to operate the ICT tools. With this scenario, we focused in the first and larger parts of the course on sufficient ICT skills.

Regarding the depth-first principle, the participants’ in-depth learning to use and apply the ICT tools within the ICT in IBSE course potentially consisted of the five stages:

Stage 1. Studying possibilities of the ICT tools
Stage 2. Mastering skills to operate the ICT tools
Stage 3. Designing the ICT in IBSE lesson that makes use of the ICT tools
Stage 4. Teaching the ICT in IBSE lesson with the ICT tools
Stage 5. Evaluating the ICT in IBSE try-out with the ICT tools
Chapter 5

Considering that the Slovak participants were expected to achieve basic Coach skills with all three ICT tools, we operationalised the depth-first principle in the course scenario in which the Slovak participants would study all three ICT tools in Stages 1 and 2 and specialise in only one tool by choice in Stages 3, 4, and 5. Due to the participants’ very little experience with the ICT tools, we intended a large part of the course (i.e. 4 out 5 live sessions, 3 out of 4 assignments) for participants to master ICT skills. This reduced the available time for participants later on to design and try out the ICT in IBSE lesson. Consequently, they had to specialise in only one tool (by choice) for the ICT in IBSE lesson.

For the ICT in IBSE course, the “ownership of learning” principle was operationalised by giving participants the freedom to select what to learn and how to learn it using the course scenario and support materials in order to achieve the course objectives. This operationalization would enable the course to accommodate for differences among the Slovak participants, concerning their teaching subjects, teaching experience, mastery of ICT and IBSE, teaching conditions, and attitudes towards professional learning.

5.2 Scenario of the Slovak ICT in IBSE course

In this section, we clarify how the pedagogical principles were operationalised in a concrete scenario of the Slovak ICT in IBSE course with respect to the expected attainment levels of the four course objectives. We focus on presenting the Cycle-2 course scenario, which was revised from the Cycle-1 scenario. The revisions were made by the Slovak course instructor and the researcher, based on evaluations of the Slovak course in Cycle 1, and aligned with the pedagogical principles. Where relevant in Section 5.4, we summarise revisions of the Slovak course scenario from Cycle 1 to Cycle 2. For more detail about revisions, reasons, and evaluation data, please refer to Jeskova et al. (2015b).

5.2.1 Overview of the Slovak course scenario

The scenario of the Slovak course in Cycle 2 included five live sessions, four individual assignments, and the final defence of the ICT in IBSE lesson. Assignments 1, 2, and 3 were intended for the two or three weeks in between Sessions 2 to 5, and Assignment 4 was intended for the seven weeks in between Session 5 and the final defence (Table 5.2). Within the 40 hours of total study time, 25 hours were allocated to the five live sessions (i.e. 5 hours each), and 15 hours were anticipated for the four assignments. The time for the final defence was not counted for the total study time. The participant was allowed to be absent in only one out of five live sessions, otherwise, she or he would not be rewarded the certificate.

The Slovak ICT in IBSE course was taught by two course instructors. To ensure personalised support for participants while practicing the ICT tools, we divided the Slovak group of 25 participants into two parallel groups, following the same scenario but on different days. Consequently, the instructor per participant ratio was about one per six.
Table 5.2. Summary of intended activities in live sessions and requirements for individual assignments in Cycle 2 of the Slovak ICT in IBSE course.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time frame*</th>
<th>Participants’ activities</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session 1</strong> (a day)</td>
<td>5 hours</td>
<td>• Listening to the ICT in IBSE framework</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Listening to the introduction and demonstration about the <em>data-logging tool</em></td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practising the <em>data-logging tool</em> through the Coach introductory and tutorial activities</td>
<td>In pairs</td>
</tr>
<tr>
<td><strong>Session 2</strong> (a day)</td>
<td>5 hours</td>
<td>• Listening to demonstration about <em>Coach data analysis and processing</em></td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practising <em>Coach data logging, analysis, and processing</em> through the Coach exemplary activities</td>
<td>In pairs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discussing how to design an ICT in IBSE lesson</td>
<td>Plenary</td>
</tr>
<tr>
<td>Assignment 1**</td>
<td>3 weeks</td>
<td>• Developing a Coach data-logging activity from scratch</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reading the introductory slides about Coach video measurement</td>
<td></td>
</tr>
<tr>
<td><strong>Session 3</strong> (a day)</td>
<td>5 hours</td>
<td>• Discussing problems related to Assignment 1</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Listening to the introduction and demonstration about the <em>video-measurement tool</em></td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practising the <em>video-measurement tool</em> through the Coach introductory, tutorial, and exemplary activities</td>
<td>In pairs</td>
</tr>
<tr>
<td>Assignment 2**</td>
<td>2 weeks</td>
<td>• Developing a Coach video-measurement activity from scratch</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reading the introductory slides about Coach modelling</td>
<td></td>
</tr>
<tr>
<td><strong>Session 4</strong> (a day)</td>
<td>5 hours</td>
<td>• Discussing problems related to Assignment 2</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Listening to the introduction and demonstration about the <em>modelling tool</em></td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Practising the <em>modelling tool</em> through the Coach introductory, tutorial, and exemplary activities</td>
<td>In pairs</td>
</tr>
<tr>
<td>Assignment 3</td>
<td>3 weeks</td>
<td>• Developing a Coach modelling activity from scratch</td>
<td>Individual</td>
</tr>
<tr>
<td><strong>Session 5</strong> (a day)</td>
<td>5 hours</td>
<td>• Discussing problems related to Assignment 3</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discussing sample ICT in IBSE activities at different inquiry levels</td>
<td></td>
</tr>
<tr>
<td>Assignment 4</td>
<td>7 weeks</td>
<td>• Designing a complete ICT in IBSE lesson plan</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Trying out the ICT in IBSE lesson with pupils</td>
<td></td>
</tr>
<tr>
<td><strong>Final defence</strong> (three half days)</td>
<td></td>
<td>• Presenting and evaluating the ICT in IBSE lesson plan and try-out</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Taking the computer performance test</td>
<td></td>
</tr>
<tr>
<td>Follow-up meeting</td>
<td></td>
<td>• Sharing ICT in IBSE teaching experience a half year after the course</td>
<td>Plenary</td>
</tr>
</tbody>
</table>

(*) The course was spread over 15 weeks. “Hours” mean actual hours of work within the course. “Weeks” indicate the period during which time would be spent on the course assignments.

(**) While carrying out individual assignments, the participants were encouraged to use the support materials and the online support.
5.2.2 Support materials

In Chapter 3, Section 3.1.4, we described the following Coach support materials for the general design of the ICT in IBSE course:

- **S**: Introductory slides for the ICT tools and possibilities of using these tools
- **C1**: Coach introductory materials to illustrate the Coach platform
- **C2**: Coach tutorial materials to practice manipulation skills with the Coach tool
- **C3**: Coach exemplary materials about how to integrate the Coach tool in inquiry-based science lessons

These support materials were used for the Slovak ICT in IBSE course and had been translated into Slovak by the local course instructor.

For the participants to design and teach an ICT in IBSE lesson, *in addition to the Coach exemplary activities*, we selected exemplary IBSE lesson plans that were developed within the ESTABLISH project. The ESTABLISH exemplary lessons\(^3\) a) are about particular science topics (e.g. sound, designing a low energy home), b) follow certain patterns of inquiry teaching (i.e. five patterns from interactive demonstration to open inquiry, see Chapter 2, Section 2.2.3), and c) use certain ICT/IBSE materials and provide thorough guidance of how to use these materials.

In Chapter 3, Section 3.1.4, we described Forms 1, 2, and 3 for written reports about individual assignments. However, we did not use these forms for the Slovak ICT in IBSE course because the Slovak participants had sufficient time in live sessions to report and discuss their assignments. They were just required to submit their assignment products (e.g. their own Coach activities and ICT in IBSE lesson plans). About the guidelines for the participants to design an ICT in IBSE lesson, we used the ESTABLISH lesson-plan form\(^4\), on which the ESTABLISH exemplary lessons were based. This lesson-plan form is similar to Form 2, described in Chapter 3, Section 3.1.4.

5.2.3 Programme for live sessions and requirement for individual assignments

Each of *Sessions 1 to 4* was devoted to mastery of one of the three ICT tools: data logging, video measurement, dynamical modelling and their generic feature: processing and analysis of data (Table 5.2). In each session, the course instructor first introduced basic concepts and possibilities of a particular ICT tool through introductory slides (S) and demonstrations with the Coach software (Figure 5.3a). The participants then practiced that tool through the Coach introductory, tutorial, and exemplary activities (C1, C2, C3) and consulted the course instructor as needed (Figure 5.3b).

After each live session, as an assignment for two or three weeks (*Assignments 1, 2, and 3*), the participant had to create a complete Coach activity from scratch and submit this Coach activity before the subsequent session. Additionally, the participants were required a) to continue practicing with the Coach support materials that they did not yet use in the live session and b) to read the introduction slides about the tool, which would be introduced in the

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\(^3\) To access the ESTABLISH exemplary lessons, use the link: http://www.establish-fp7.eu/resources/units.html

\(^4\) To access this form, use the link: http://establish-fp7.eu/sites/default/files/general/ESTABLISH_D1-1_FRAMEWORK_UNITS.pdf
subsequent session. At the beginning of the subsequent session, problems related to the assignment were discussed.

For the participants to have sufficient time to prepare their ICT in IBSE lesson, the course instructor already introduced to the ICT in IBSE framework in Session 1 and discussed how to design an ICT in IBSE lesson, using the lesson-plan form in Session 2. In Session 5, the participants discussed about how to design and teach an ICT in IBSE lesson in more detail. They first played the pupil role in carrying out sample ICT in IBSE activities, including Coach exemplary activities and the ESTABLISH exemplary lessons. These sample activities were aligned at different patterns of inquiry teaching: interactive demonstration, guided discovery, guided inquiry, bounded inquiry, and open inquiry (see Chapter 2, Section 2.2.3). After that, the participants discussed in plenary about how ICT and IBSE was incorporated in each sample activity.

After Session 5, as Assignment 4 for seven weeks, the participants had to design their own ICT in IBSE lesson plan and submit before the final defence. The participants were highly recommended to try out their ICT in IBSE lesson plans with pupils (Figure 5.3c) before the defence. If the ICT in IBSE try-out was effective to some extent, the participant would get a bonus point in the committee's judgment of their Assignment 4.

![Photographs of Slovak participants' activities in chronological order](image)

(a) (b) (c) (d)

Figure 5.3. Photographs of Slovak participants' activities in chronological order: a) listening to introductions and demonstrations about the ICT tool, b) practising manipulation skills with Coach, c) trying out the ICT in IBSE lesson with pupils, and d) reporting back in the final defence.

In the final defence (scheduled as three half-day sessions), each participant had 15 minutes to present their ICT in IBSE lesson plan to the three-member committee and to highlight outcomes from the classroom try-out (Figure 5.3d). The committee then commented
and asked questions. The participants were encouraged to attend the entire session to learn from each other. The ICT in IBSE lesson plans plus Coach activities were shared among participants for wider use. The atmosphere of the final defence was not stressful and critical; rather it was constructive, enjoyable, but serious. After the presentation and discussion about the ICT in IBSE try-out, the participants took the computer performance test.

Six months after the course, the participants were invited to a half-day follow-up meeting in which they shared their new experiences concerning the ICT in IBSE teaching, got updated about the ICT tools, and received extra ICT in IBSE materials.

5.2.4 Online support and coordination of the course

The online support was to provide the participants with ongoing access to support materials and with consultation from the course instructor. The online platform with the support materials and the consultation forum for the participants were designed and implemented within the ESTABLISH project’s Moodle environment. The participants were encouraged to consult each other and the course instructor about their problems via the online forum while working on the assignments. They had to submit assignments (i.e. Coach activities and the ICT in IBSE lesson plan) via the Moodle platform before the deadline. The course instructor checked the forum and/or email regularly in order to react to the participants’ questions timely. Because the Slovak ICT in IBSE course was already in the routine implementation conditions, there was no one to a) track the progress of the participants’ assignment, b) send reminder emails, or c) visit the school for observation of the ICT in IBSE try-out.

5.3 Evaluation framework, instruments, and cooperation in the Slovak case study

As mentioned in Section 5.1.1, the Slovak case study was to test validity of the pedagogical principles and transferability of the ICT in IBSE course in the Slovak context. In order to arrive at the test conclusions, we addressed the following evaluation questions:

A. About implementation of the pedagogical principles and the support materials in the Slovak context
   A1: Was the “one theory-practice cycle” principle implemented faithfully?
   A2: Was the “distributed learning” principle implemented faithfully?
   A3: Was the “depth first” principle implemented faithfully?
   A4: Was the “ownership of learning” principle implemented faithfully?
   A5: Were the support materials useful for participants?

B. About effectiveness of the Slovak ICT in IBSE course
   B1: Did the course achieve its awareness objective?
   B2: Did the course achieve its ICT mastery objective?
   B3: Did the course achieve its ICT in IBSE objective?
   B4: Did the course achieve its motivation objective?

To address these questions, we adapted and used the evaluation framework and the instruments, which were described in Chapter 3. We adapted the following instruments for data collection and analysis in the Slovak case study:

Q1: Pre-course questionnaire
Q2: Post-course questionnaire
Q3: Follow-up questionnaire

O3: Observations of live sessions by the course instructor

R1: Report on practice with the ICT tool (the products of Assignments 1, 2, 3)

R2: Report on the ICT in IBSE lesson plan (the product of Assignment 4)

R3: Report on the ICT in IBSE try-out

I: Inquiry-analysis Inventory

T: Computer performance test

The adaptations were based on the research conditions and the Slovak course scenario.

In particular, the Slovak course instructor was asked a) to write structured and extensive observation reports (O3) about Sessions 1 to 5 and the follow-up meeting and b) to record videos of these live activities. The researcher was only present at the last part of the course to observe the final defence (R3) and administer the computer performance test (T). Participants’ reports on their ICT in IBSE try-outs (R3) were partly in written form: presentation slides and partly in oral form: live presentations in the formal-assessment session (final defence). To analyse the participants’ try-out report, we used the participants’ reports, the observation notes of the researcher, and the final judgements of the course instructors. Table 5.3 shows which instruments were used and combined to collect and analyse data about a) the implementation of the pedagogical principles and the support materials in the Slovak context and b) the effectiveness of the Slovak ICT in IBSE course.

Table 5.3. Overview of instruments per evaluation question in the Slovak case study.

<table>
<thead>
<tr>
<th>Evaluation questions</th>
<th>Instruments*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1: Was the “one theory-practice cycle” principle implemented faithfully?</td>
<td></td>
</tr>
<tr>
<td>A2: Was the “distributed learning” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A3: Was the “depth first” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A4: Was the “ownership of learning” principle implemented faithfully?</td>
<td>✓</td>
</tr>
<tr>
<td>A5: Were the support materials useful for participants?</td>
<td>✓</td>
</tr>
<tr>
<td>B1: Did the course achieve its awareness objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B2: Did the course achieve its ICT mastery objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B3: Did the course achieve its ICT in IBSE objective?</td>
<td>✓</td>
</tr>
<tr>
<td>B4: Did the course achieve its motivation objective?</td>
<td>✓</td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates which instruments were used for each question.
Chapter 5

The instruments and support materials were translated into Slovak by the Slovak course instructors. These instructors were PhD holders, experienced science-teacher educators, and science-education researchers; they regularly offered in-service ICT/IBSE trainings for large groups of science teachers (Jeskova et al., 2015a). Moreover, they had participated in several European projects on IBSE, including the ESTABLISH project. Within the ESTABLISH project, they were involved in the development of the Coach activities, introductory slides, and the ICT in IBSE exemplary materials, which were used as support materials in the ICT in IBSE course. Relevant open responses of the participants were translated by the instructors from Slovak to English.

The researcher did not master the Slovak language but did observe the live presentations in the final defence (R3) and the computer performance tests (T) with interpretation assistance of the course instructors. The other parts of the data were collected via the Moodle platform (R1, R2), via the online questionnaire platform (Q1, Q2, and Q3), and via the observation report of the course instructor (O3). Because of this research context, we discussed with the Slovak instructors via email during the Slovak case study. The email discussions involved different aspects of the case study such as data-collection methods, data-analysis outcomes, and adaptation and revisions of the Slovak course. By this way, evaluations of the Slovak instructors about the implementation and effectiveness of the course were taken into account and triangulated with the data-analysis outcomes when possible. Finally, the Slovak course instructors and the researcher agreed on the conclusions and discussions of the case study and together reported the implementation and evaluation of the course at several national and international conferences on science education (e.g. Jeskova et al., 2015b; Jeskova et al., in press). This chapter was checked by one of the course instructors.

5.4 Implementation of the pedagogical principles and the support materials in the Slovak context

In this section, we present the data and discuss the implementation of the pedagogical principles and the support materials in the Slovak context (Cycle 2). Where relevant, we show the data from Cycle 1 in comparison with those from Cycle 2 in order to discuss the implementation of the pedagogical principles further.

5.4.1 About the “one theory-practice cycle” principle

a) Results

Based on participants’ reports (R2 and R3) in Cycle 2, we recorded that all 27 participants could design their own ICT in IBSE lessons; 20 participants (74% of N=27) managed to try out their ICT in IBSE lessons with pupils before the final defence (Table 5.4). According to the formal judgements of the course instructors in the final defence, the ICT in IBSE lessons were generally of good quality. For more detail about evaluations on the participants’ lesson plans and classroom try-outs, see Section 5.5.3. In comparison with Cycle 1, the Slovak course in Cycle 2 was much more successful in stimulating and supporting the participants to complete one theory-practice cycle.
Table 5.4. Number of Slovak participants in each cycle, who completed the ICT in IBSE lesson plan and the ICT in IBSE try-out before the final defence.

<table>
<thead>
<tr>
<th>Number of participants</th>
<th>Cycle 1 (N=39)</th>
<th>Cycle 2 (N=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completing the ICT in IBSE lesson plan</td>
<td>37</td>
<td>27</td>
</tr>
<tr>
<td>Completing the ICT in IBSE try-out</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

b) Discussion

In Cycle 1, although 37 out of 39 participants completed their ICT in IBSE lesson plan, only 10 participants (26% of N=39) managed to try out their lesson plans before the final defence (Table 5.4). The evaluation of Cycle 1 (Jeskova et al., 2015b) indicated several reasons. First, the participants only became aware of the suggestion for try-out of their ICT in IBSE lesson plans in the last live session. Consequently, they had only five weeks before the final defence for both designing and trying out the lessons. Second, many lesson plans of the Cycle-1 participants required equipment, which schools did not have yet.

Consequently, we revised the course scenario for Cycle 2. In particular, the course duration was extended from 12 weeks in Cycle 1 to 15 weeks in Cycle 2, including 7 weeks anticipated for the classroom try-out. Moreover, the course instructor strongly recommended the participants to design and try out the ICT in IBSE lesson right at Session 1. The ICT in IBSE framework and the lesson-plan form were discussed at the beginning of the course so that the participants could start to design the lesson plan early and have sufficient time to prepare for the try-out. In case the equipment was lacking, the participants were encouraged to design the ICT in IBSE lesson in the pattern of interactive demonstrations with one computer and/or one set of experiment. These revisions and encouragements worked out in Cycle 2 as the percentage of participants who could try out their ICT in IBSE lesson before the final defence increased remarkably from 26% to 74% (Table 5.4).

5.4.2 About the distributed-learning principle

a) Results

Based on the participants’ estimates via the post-course questionnaire (Q2), we calculated that the Cycle-2 participants actually spent 10 hours (SD=1.5) for practicing the ICT tools (Assignments 1, 2, and 3) and 6 hours (SD=2.5) for designing and trying out the ICT in IBSE lesson (Assignment 4). The 16 study hours (SD=2) outside live sessions in total matched well with our anticipation: 15 hours out of the total 40-hour study time.

The Moodle log showed that the participants often visited the Moodle platform to upload their own assignments and to download the course’s support materials and assignment products of peers. They reported via the post-course questionnaire (Q2) that the online platform provided an easy access to the plentiful resource of support materials and to timely support from the course instructor. It also enabled the simple upload and provided a space to share the Coach activities and ICT in IBSE lesson plans among participants.

The participants were asked via the post-course questionnaire (Q2) whether they preferred the distributed scenario of the course as compared with a compact Coach workshop. Of 24 respondents, 18 participants (75%) preferred the distributed scenario. These participants
appreciated the distance part of the course where they could work on their own time and pace with support materials. The six others (25% of N=24) did not like many afternoon sessions over several months because it was difficult for them to arrange their agenda for half days off. After the morning teaching, the 5-hour intensive study in the afternoon was exhausting.

Based on participants’ responses to the question: how would you prefer to change the time consumed for each activity in each live session of the course? (Q2, 3-point scale, -1=less time, 0=unchanged, 1=more time), we computed the weighted average. The average reflects to what extent the group of participants desired more or less time for each live activity. Figure 5.4 shows that the participants in Cycle 2 were quite satisfied with the timing for live activities.

![Figure 5.4](image)

Figure 5.4: The Slovak participants’ suggestions to change the timing of the main live activities in each cycle (3-point scale, -1=less time, 0=unchanged, 1=more time).

b) Discussion

In Cycle 1, the course instructor spent most of the contact time to guide all participants to practice the Coach support materials through plenary step-by-step instructions. The beginning of plenary instruction on practicing Coach activities went smoothly, as the participants were still fresh, so they were able to keep attention. However, later on, it turned out to be too much new information for them to follow and remember. The participants started to be stuck at different steps, but the course instructor could not help them in time because she was busy keeping the plenary instruction on track. Some participants were left behind. After that, she adjusted the pace slower (to ensure all can follow) or stopped sometimes to help left-behind participants. As a result, she could not cover all of the intended activities and leave the participants to practice the remained activities (i.e. Coach exemplary activities) on their own. According to the course instructor, the longer practicing of the Coach support materials under plenary instruction, the more frustration the participants and even the course instructor got. This was why the Cycle-1 participants desired more time for practicing the Coach support materials in groups, especially the Coach exemplary activities. Figure 5.4
also shows that the Cycle-1 participants wanted more time for discussing the sample ICT in IBSE activities at different inquiry levels.

In Cycle 2, the practice to acquire ICT skills was shifted from plenary instruction to group work. The course instructors first guided practice of one or two Coach activities via plenary instruction and then let the participants to practice others in groups of two. They went around groups to help participants as needed to get over initial hurdles. Moreover, in order to reduce the time for the plenary introduction to the ICT tools, the course instructor focussed on direct demonstrations with the Coach software and sensors and left the introductory slides for the participants to read in advance as part of Assignments 1, 2, and 3.

Additionally, the total study time was extended from 30 hours in Cycle 1 to 40 hours in Cycle 2. One more live session, five instead of four, was allocated. Consequently, the course instructor could spend more time for participants to discuss how to integrate the ICT tools in an inquiry lesson. These revisions proved to be effective in Cycle 2, considering that the Cycle-2 participants were more content with the live activities (O3) than the Cycle-1 participants were. However, their suggestion for a change in timing was still in the trend: a) more time for the small-group practice with the ICT tool and for the guideline on designing the ICT in IBSE lesson and b) less time for the plenary introduction and instruction (Q2, O3) (Figure 5.4).

5.4.3 About the depth-first principle

The participants studied possibilities and practiced all three ICT tools in the first four live sessions (5 hours each) and for three individual assignments (about 10 hours). The total 30 hours (incl. 20 contact hours) seemed to be appropriate to compensate for a low entrance level of the ICT mastery and to cover the TCK for all three ICT tools, considering participants’ sufficient ICT skills after the course (see Section 5.5.2).

Of 27 participants, 10 participants specialised in the data-logging tool for their ICT in IBSE lessons, 7 participants specialised in the video-measurement tool, and 5 participants specialised in the modelling tool. The 5 others combined the use of the modelling tool with either the data-logging tool or the video-measurement tool. In their ICT in IBSE lessons, modelling data were compared with experimental data from the measurement with sensors or from the video measurement. This combined use of the ICT tools was relevant because it stimulated pupils to move back and forth between the theoretical and physical worlds (see Chapter 2, Section 2.1.2).

In the follow-up meeting, 20 participants were asked if they preferred the course scenario, in which the participants specialised in only one tool by choice to master ICT skills and then spent most of the study time for preparing, executing, and evaluating the classroom try-out of the ICT in IBSE lesson with the chosen tool. All of these participants preferred the Slovak course scenario to the proposed scenario. They desired basic mastery of all three ICT tools. However, they also reported that they appreciated very much the ICT in IBSE try-out and the discussion about the try-out in the final defence. These resulted in their confidence and motivation to try out more ICT in IBSE lessons after the course (see also Section 5.5.4).
5.4.4 About the “ownership of learning” principle

According to the course instructors (O3), the participants practiced the ICT tools in groups seriously and were actively engaged in plenary discussions. The majority of the participants submitted the assignments in time and in good quality. In particular, the course instructors judged that of 27 ICT in IBSE lesson plans (R2), 17 lesson plans (63%) were thoroughly written with sufficient details; 7 others (26%) were thoroughly structured but lacked some important details. There were only three lessons (11%) that were documented superficially. Of 27 participants, 25 participants made an active effort to try out their ICT in IBSE lessons. The content aims of these lessons varied, but all were within the formal curriculum. One third of the try-out topics were connected to real-life situations. For example, decelerated motion of a sliding child: determination of the friction coefficient (video measurement); police car and helicopter chasing thieves: position and velocity versus time graphs (modelling); electric current in mineral water, tap water, and ion drink for sportsmen (data logging). These were important results with regard to the participants’ ownership of learning, considering that there was no one to track the assignment process and remind them about the deadline. However, there were a few participants not taking their ownership of learning. This was reported by the course instructor (O3) as follows:

I observed a wide variety of participants’ personal interest and efforts. Many teachers tried to learn as much as possible. They took much time to do the assignment seriously and applied it immediately with pupils. When facing obstacles, they reviewed the given Coach activities for hints and tried different solutions to get over the problems themselves. A few participants showed their efforts to transfer their new experience with Coach to manipulate Vernier equipment and software in their schools [some schools used Vernier rather than Coach]. Meanwhile, some teachers were easy to get lost as working with Coach alone. Some emailed for getting help, but did not progress further, so waited for the next live session. There were a few participants showing low attitude of learning. They slightly modified someone's assignment for submission or submitted their superficial assignments mainly in order to get the certificate.

Via the post-course questionnaire (Q2), 19 participants (out of 27) reported that they implemented the Coach exemplary activities and/or their own Coach activities (Assignments 1, 2, and 3) with pupils, although such implementations (without clear IBSE intentions) were not counted for the final defence. Many participants borrowed equipment from the course instructor to practice the use of the ICT tools in the classroom. In the live discussion (O3), a few participants reported that they were happily surprised about the active engagement of their pupils in the Coach activities. Consequently, they got extra motivation to try out with other ICT tools as shared by a participant: “I saw that pupils are motivated; this motivates me as a teacher to do more”.

The computer test (T) was not part of the formal assessment, because it was not proposed in the programme to be accredited. The participants were invited to take the test after receiving the certificate. However, all 27 participants took the test and carried it out seriously. Many participants looked frustrating with the test problems regarding the given Coach activities, but they did not give up. To find clues, some opened their notes taken in live sessions a few weeks ago and/or tried out different tentative solutions. After the test, the participants asked us to let them copy the test materials to investigate further at home and to share with their colleagues.
5.4.5 About the support materials

Via the post-course questionnaire (Q2), we asked the participants: *to what extent are the support materials useful to you in learning to use and apply the ICT tools in the inquiry-based lesson?* To respond, the participants answered on a 5-point scale (1 = not at all useful, 5 = extremely useful) for each material or selected the option: “I did not use it, so I have no idea”. Of 27 participants, 25 participants responded to the question. The 25 respondents used all of the support materials and evaluated these materials as very useful (Table 5.5). According to the participants, the Coach introductory and tutorial activities were self-explanatory and easy to follow in practicing skills with Coach. The Coach exemplary activities and the ESTABLISH exemplary lessons proved to be adaptable and applicable in their teaching conditions.

Table 5.5. The Slovak participants’ evaluation on the usefulness of each material to their learning during the course (5-point scale, 1 = not at all useful, 5 = extremely useful).

<table>
<thead>
<tr>
<th>Support materials</th>
<th>Usefulness of the material - Weighted average (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory slides</td>
<td>4.2 (0.5)</td>
</tr>
<tr>
<td>Coach introductory activities</td>
<td>4.3 (0.6)</td>
</tr>
<tr>
<td>Coach tutorial activities</td>
<td>4.3 (0.4)</td>
</tr>
<tr>
<td>Coach exemplary activities</td>
<td>4.4 (0.5)</td>
</tr>
<tr>
<td>Instructional video clips</td>
<td>4.3 (0.5)</td>
</tr>
<tr>
<td>The ESTABLISH exemplary lessons</td>
<td>4.2 (0.5)</td>
</tr>
</tbody>
</table>

5.5 Effectiveness of the Slovak ICT in IBSE course

In this section, we evaluate to what extent the Slovak ICT in IBSE course attained its four objectives. The data are presented and discussed per each course objective.

5.5.1 Participants’ awareness of educational benefits of the ICT tools in science education

Via open-ended questions in the post-course questionnaire (Q2), we asked the participants to enumerate educational benefits of the use of data logging, video measurement, and modelling in science education. Almost all participants (25 out of 27) reacted to the questions. Each respondent enumerated one or two benefits of each of the three ICT tools. Of 25 respondents, 11 participants (44%) enumerated the benefit in letting pupils conduct their own research. Two third of the respondents (68% of N=25) remarked time efficiency of using the ICT tools in laboratory demonstration and/or in practical work. The benefits in stimulating pupils to exercise inquiry practices and in improving conceptual understanding were mentioned by 16 participants and 19 participants respectively (64% and 76% of N=25). Additionally, 15 out of 25 respondents (60%) pointed out the effects of using the ICT tools to enhance pupils' motivation towards science and make school science more meaningful. Considering all respondents together, the enumerated benefits matched with the ones that were discussed in the literature and/or reviewed in Chapter 2, Section 2.1.2.
5.5.2 Participants’ skills to operate the ICT tools

a) Results

There are several indicators for the participants’ skills to operate ICT tools: their ICT in IBSE activity, pre-post self-confidence levels of participants, and the performance test of computer skills at the end of the course.

The assignment reports on practice with the ICT tool (R1) showed that 23 of 27 participants could develop a complete Coach activity from scratch, including tables, graphs, text instructions, and illustrative images. Regarding the Coach activities for the ICT in IBSE lesson plan (R2), 19 out of 27 participants (70%) created their own, new Coach activities, whereas others (30%) modified given Coach activities. Figure 5.5 shows two examples of new Coach activities: a) using two sensors to measure speed of sound and b) modelling heat transfer between two liquids.

![Figure 5.5](image)

*Figure 5.5. New Coach activities of Slovak participants: a) measuring speed of sound with two sensors and b) modelling heat transfer between two liquids: introduction of the concept of heat capacity.*

Via the pre-course questionnaire (Q1), we asked the participants about their confidence level in regard to particular manipulations of each of the three ICT tools (Table 5.6) (5-point scale, 1 = not confident at all, 5 = extremely confident). We repeated this question in the post-course questionnaire (Q2) in order to compute the weighted average of pre- and post-confidence and then the normalised gain of the Slovak participants to each manipulation. The normalised-gain values in Table 5.6 show that through the course, the Slovak participants became much more confident in manipulating all three ICT tools. After the course, they felt confident with basic manipulations with the ICT tools (3.5 to 4.1 of the 5-point scale). About the advanced manipulations: determining the calibration factors of a sensor and developing a graphical model (Table 5.6), they were a bit less confident (3.2 of the 5-point scale).

The computer performance test included three tasks that required the participants to troubleshoot three incomplete or problematic Coach activities corresponding to the three ICT tools (see Chapter 3, Section 3.3.5). Of 27 participants, 4 participants did troubleshoot all three test problems successfully; 7 did solve two test problems; 12 could address only one test problem; and 4 did not succeed in fixing any problem. Additionally, before the test, the course instructors were asked to estimate who achieved the best ICT skills among the 27 participants, considering their observation of live sessions (O3) and judgement of the assignment reports (R1, R2). Interestingly, of 9 participants who were estimated to gain the most sufficient ICT
skills, 7 did achieve the best result of the test (i.e. 3 could solve all three problems, and 4 could solve two problems).

Table 5.6. Confidence levels before and after the course and the normalised gains of the Slovak participants for particular manipulations of the tool (5-point scale, 1=not confident at all, 5 = extremely confident).

<table>
<thead>
<tr>
<th>Confidence level</th>
<th>Pre</th>
<th>Post</th>
<th>Normalised gain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Data logging</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1. Connecting sensors and an interface to a computer</td>
<td>2.3</td>
<td>4.1</td>
<td>67 %</td>
</tr>
<tr>
<td>1.2. Setting sensor connection in the software</td>
<td>2.0</td>
<td>3.8</td>
<td>60 %</td>
</tr>
<tr>
<td>1.3. Setting time-based measurement</td>
<td>2.1</td>
<td>3.6</td>
<td>52 %</td>
</tr>
<tr>
<td>1.4. Setting event-based measurement</td>
<td>2.1</td>
<td>3.6</td>
<td>52 %</td>
</tr>
<tr>
<td>1.5. Setting a measurement based on a trigger event</td>
<td>1.9</td>
<td>3.4</td>
<td>48 %</td>
</tr>
<tr>
<td>1.6. Determining the calibration factors of a sensor</td>
<td>1.6</td>
<td>3.2</td>
<td>47 %</td>
</tr>
<tr>
<td><strong>2. Video measurement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1. Making scale settings</td>
<td>1.6</td>
<td>3.9</td>
<td>68 %</td>
</tr>
<tr>
<td>2.2. Specifying features of the co-ordinate system</td>
<td>1.7</td>
<td>3.9</td>
<td>67 %</td>
</tr>
<tr>
<td>2.3. Setting time calibration for video</td>
<td>1.5</td>
<td>3.7</td>
<td>63 %</td>
</tr>
<tr>
<td>2.4. Performing perspective correction</td>
<td>1.4</td>
<td>3.3</td>
<td>53 %</td>
</tr>
<tr>
<td>2.5. Correcting video points by dragging wrong measured points to the correct position</td>
<td>1.4</td>
<td>3.6</td>
<td>61 %</td>
</tr>
<tr>
<td>2.6. Setting point tracking by which measurement is performed automatically</td>
<td>1.5</td>
<td>3.5</td>
<td>57 %</td>
</tr>
<tr>
<td><strong>3. Modelling</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1. Using a given model to understand a phenomenon</td>
<td>1.7</td>
<td>3.8</td>
<td>64 %</td>
</tr>
<tr>
<td>3.2. Exploring to gain insight into a given model</td>
<td>1.6</td>
<td>3.5</td>
<td>56 %</td>
</tr>
<tr>
<td>3.3. Making a small change to a given model</td>
<td>1.4</td>
<td>3.5</td>
<td>58 %</td>
</tr>
<tr>
<td>3.4. Developing a graphical model</td>
<td>1.3</td>
<td>3.2</td>
<td>51 %</td>
</tr>
</tbody>
</table>

The participants were able to demonstrate their basic manipulations during the computer performance test and in the submitted test result files (T). They manipulated the software fluently; went back and forth between panes and settings to find problems; and changed parameters to try out solutions. When facing the problems, they revealed their lack of trouble-shooting experience. For example, the basics of video measurement: scale and time calibration were not checked first, but last. They spent too much time to repeat the measurement without intentional changes in the calibration and/or repeatedly check the graph where the problems were seen. Sometimes, they coincidentally went to the setting where a wrong parameter needed to be changed, but they did not recognise the needs to change (e.g. sampling frequency: 5000 Hz instead of 50 Hz and measurement time: 20 ms instead of 10s). Some participants even showed their lack of content knowledge as follows:

Some participants did not know when a tuning fork emits a pure tune (several seconds after being stricken). Some clicked the button to start the measurement first, then struck the tuning fork; or struck the tuning fork first and then clicked the start button instantly. They did not place the sound sensor in front of (or inside) the resonance box. They got a weak sound signal because of just holding the sound sensor around a U-shaped bar. In some cases, the tuning fork was not attached firmly to the box.
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Of the participants who troubleshoot a problem successfully, almost all found out the solutions in the last minutes of the test after much struggling of searching and trying out solutions.

b) Discussion

The test performance and results confirmed the sufficient manipulation skills of the Slovak participants in operating the three ICT tools and revealed their lack of troubleshooting skills in general. Just a minority of the participants could troubleshoot most TCK problems of the Coach activities within a limited time. However, the Slovak participants were not afraid of facing the TCK problems. They were confident enough to define strategies and try out solutions. After the test, one of the participants said:

The test would not be difficult if there was no time limitation, and it was possible to discuss with someone else. It was the first time for us to carry out this kind of computer test. Thanks to the experience of successfully fixing one or two Coach activities, we just learnt what were the basics of troubleshooting.

Actually, the participants lacked the troubleshooting experience, and the test proved to be a good tool for them to learn the troubleshooting skill.

c) Recommendation

In the Slovak ICT in IBSE course, the participants did an individual assignment with a particular ICT tool (e.g. data logging), but in the next session and after that, they had to work with a different tool. In the second half of the course, they specialised in only one tool to design and try out an ICT in IBSE lesson. Additionally, they did not often have opportunities to use the ICT tools in teaching practice. Consequently, as reported by the participants, when taking the test, they did not really remember details about the tool that they studied many weeks ago at the beginning of the course. Therefore, it should be more relevant if we provide a tool-specified test (20 minutes) at the beginning of each live session (i.e. the data-logging test at Session 3, the video-measurement test at Session 4, the modelling test at Session 5). Each test is to a) evaluate what the participants have learnt through the individual assignment and b) make them aware of what is most important for the particular tool before switching to studying the other tools. In this case, the computer test would be for formative assessment. Moreover, we would administer another computer test to measure the attainment of the ICT-mastery objective. However, this time, the participants would take only one test problem related to the ICT tool in which they specialise for the ICT in IBSE lesson.

5.5.3 Participants’ ability to design, implement, and evaluate an ICT in IBSE lesson

a) Results

We used the inquiry-analysis inventory to analyse all 27 ICT in IBSE lesson plans and to code which inquiry components were operationalised as learning opportunities for pupils. Around 7 inquiry opportunities (SD=5) were operationalised per lesson (per participant). The four inquiry opportunities operationalised in most lesson plans (Figure 5.6) were:

- Component 2.1: manipulating software/apparatus to construct and/or execute the experiment/model (22 out of 27)
• **Component 2.2:** observing and/or measuring experimental variables or determining resulting values of modelling variables (24 out of 27)
• **Component 2.3:** recording experimentation/modelling data (24 out of 27)
• **Component 3.3:** determining qualitative and/or quantitative relationships (25 out of 27)

The list of 22 categories of inquiry skills within the ICT in IBSE activity:

1. **Conception, planning and design**
   - 1.1 formulates a question
   - 1.2 formulates an hypothesis or expectation
   - 1.3a defines variables of experiment/model
   - 1.3b defines how each variable will be measured or modelled
   - 1.3c defines procedures to analyse experimentation/modelling data
   - 1.4 predicts results of experiment/model based on its design

2. **Execution of experiment/model**
   - 2.1 manipulates software and/or apparatus
   - 2.2 measures/determines values of variables
   - 2.3 records experimentation/modelling data
   - 2.4 decides/explains experimentation/modelling techniques
   - 2.5 works according to the own design

3. **Analysis and interpretation**
   - 3.1 chooses representations of data
   - 3.2 determines accuracy and precision of data
   - 3.3 determines relationships
   - 3.4 compares the results to the hypothesis/prediction
   - 3.5 explains experiment/modelling results
   - 3.6 discusses limitations of the experiment/model
   - 3.7 proposes generalizations of the results

4. **Applications and follow-up**
   - 4.1 predicts on basis of obtained results
   - 4.2 formulates new questions
   - 4.3 formulates hypotheses for follow-up
   - 4.4 applies the techniques to a new problem

**Figure 5.6.** Number of Slovak lesson plans (out of total 27) in which each inquiry component (1.1 to 4.4) was operationalised as a learning opportunity (and not a prescriptive recipe) for pupils. Each participant designed one ICT in IBSE lesson plan.

Figure 5.6 also shows that about a half of the lesson plans were focused on pupils predicting results of the experiment/model (component 1.4) and then comparing the actual results to the prediction (component 3.4). Very few or no participants intended for their pupils to design the experiment/model (components 1.3a, 1.3b, and 1.3c) and work according to their own design (component 2.5). These analysis outcomes matched with the judgements of the course instructor: 20 out of 27 ICT in IBSE lesson plans (Cycle 2) fell in the two first patterns of the inquiry continuum (Figure 5.7). Under the patterns of interactive demonstration (5 out of 20) and guided discovery (15 out of 20), the teachers intended to take control of the
learning process through a plenary demonstration or a prescriptive worksheet for the group work. The investigation problems and procedures were given by the teacher, so pupils’ independence was low (Jeskova et al., in press).

Figure 5.7. Number of Slovak ICT in IBSE lesson plans evaluated by the course instructors and categorised in certain patterns of inquiry teaching.

In the final defence, each participant was required to summarise her or his ICT in IBSE lesson plans, self-evaluate if the plan was executed as intended, and suggest possible revisions for the next classroom implementation. After that, the course instructors raised discussion questions about particular issues of the classroom execution and then finally judged the design and implementation of the ICT in IBSE activity. According to the course instructors, the majority of participants could implement their ICT in IBSE lesson plans faithfully and self-evaluate the classroom try-outs appropriately. These participants could show relevant evidence (e.g. scanned worksheet, photo, Coach result files) to support their evaluation points regarding the achievement of their inquiry intentions (Figure 5.8). Several participants reported their negative try-out experience: they talked too much, and the tasks were too demanding, and so their pupils were not engaged in the intended inquiry practices. Regarding the future use of their ICT in IBSE lesson plans, about one third of the participants would not change the lesson plans. The others would like to:

- make small changes in the worksheet (e.g. more detailed instructions);
- simplify the Coach activity (e.g. reducing the number of tasks or eliminating the complicated one);
- arrange a work group of two instead of three or four.

Figure 5.8. A scanned worksheet and a classroom photo as evidence, which was used by a participant to support her evaluation point.
As experienced teachers, the Slovak participants did not have big problems to design a thorough lesson plan, implement it, and point out deviations in the classroom implementation of the lesson. The remarkable problem was that they intended and offered very few opportunities for pupils to be involved in the design of the experiment/model and the formulation of a hypothesis. None of the ICT in IBSE lessons fell in the bounded-inquiry and open-inquiry patterns (Figure 5.7). Evidently, the Slovak participants preferred ICT in IBSE activities with teacher’s sufficient guidance. This was not only because Slovak pupils lacked experience of inquiry learning (see Section 5.1.2) but also because the participants themselves did not have much experience with inquiry strategies. According to the course instructor’s observation (O3), when asked to design an experiment and/or formulate a hypothesis for a given problem in Session 5, the participants found it difficult regardless whether ICT was integrated or not. The participants shared that they were not optimistic about the successful implementation of the inquiry activities in which pupils were given much freedom.

5.5.4 Participants’ motivation to study the ICT tools further and to try out more ICT in IBSE lessons

a) Results

Via an open-ended question in the post-course questionnaire (Q2), we asked the participants about their plans to apply the ICT tools in their teaching in the near future. Of 23 participants who responded to the question, 21 participants devised particular plans to develop and implement more ICT in IBSE activities in the classroom. For example, seven participants planned to look into the exemplary materials in detail and try them out during the next school year. Six participants intended to a) introduce their colleagues to the course materials and ICT in IBSE lesson plans developed within the course and b) integrate the ICT tools in the experimental part of the school final exam. Almost all participants planned to keep contact with the course instructors; to borrow equipment from the university; and to get update about new tailor-made ICT in IBSE activities for science teachers nationwide. They were eager to participate in another course that was for advanced Coach users and that was focussed on development of ICT in IBSE materials for the Slovak curriculum.

According to the course instructors, the participants stayed in contact with them after the course, so it was easy for them to arrange the follow-up meeting. The meeting was six months after the Cycle-2 course and one and a half year after the Cycle-1 course. Before the meeting, we sent the follow-up questionnaire to all 66 participants of the course and received 44 responses, including 24 out of 39 participants in Cycle 1 (62%) and 20 out of 27 participants in Cycle 2 (74%). We interviewed all participants (N=20) who attended the follow-up meeting to get more insight into their responses to the follow-up questionnaire.

Of 44 respondents, 34 participants (77%) continued to study the ICT tools on their own 0.5 to 1.5 years after the course; 32 participants (73%) taught more lessons with data logging; 23 participants (53%) taught more lessons with video measurement; 13 participants (30%) taught more lessons with dynamical modelling. About the IBSE lessons, 16 participants (36% of N=44) taught more ICT in IBSE lessons, and 21 participants (48% of N=44) taught more IBSE lessons but not using the ICT tools. Via open-ended questions and
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In the follow-up meetings, particular ICT in IBSE try-outs were reported. However, 4 Cycle-1 participants and 3 Cycle-2 participants (out of 44 respondents) did not teach either ICT or IBSE lessons since completing the course.

Generally, the 44 respondents taught ICT and IBSE lessons more often than they did before the course (self-report). They felt quite competent in teaching with the data-logging tool, the video-measurement tool, and the integration of these tools in IBSE (3.2 to 3.5 of the 5-point scale). However, they were not yet so confident in teaching with the modelling tool (2.7 of the 5-point scale). According to the course instructors and the discussion in the follow-up meeting, there were about 10 participants, who a) regularly used the data-logging and video-measurement tools in teaching practice, b) guided pupils using these ICT tools in scientific competitions\(^5\) among teams of secondary school pupils, and c) became leaders of innovation efforts at the school or national levels. These 10 teachers were also the ones who performed the best during the course.

In the follow-up meeting, the participants (N=20) showed their high motivations concerning the ICT and IBSE teaching. For sustainable incorporation of ICT and IBSE, the participants discussed the idea of developing a database of tailor-made ICT in IBSE activities aligned with the new inquiry-oriented curriculum and making it searchable and downloadable on a website (e.g. based on the tool, the topic, and the grade level of pupils). Together with the database, the participants suggested regular follow-up meetings of the teachers, who participated in the ICT and IBSE course. This was aimed at developing a community of innovative teachers, in which the teachers have opportunities to share their ideas, to exchange ICT in IBSE lesson materials, and to get update about new strategies and technologies of science teaching and learning. The course instructors supported these ideas and reflected on the follow-up discussion as follows:

Incorporating ICT and IBSE in teaching practice is an ongoing process. We cannot expect that the participants can make changes quickly. Some obstacles are very difficult to tackle, whereas some others are easier to overcome. For example, the participants need more lessons per week and smaller classes that we cannot help. Additionally, they require more equipment. This is good because it means they really use it and want to use it. We can lend them equipment or open our university labs for their pupils. This support actually happens very often. The participants got motivation and really used it since they left the course. However, to make real changes in the classroom, we need other and concerted efforts regarding curriculum, equipment, examination, and so on. There is now less and less teachers’ complaints about equipment, and this is a positive step forward.

Via the follow-up questionnaire and meeting, the participants were asked to look back and evaluate the effects of the ICT in IBSE course. Generally, the participants appreciated the content, organization, and support of the course. Of 44 respondents, 35 participants (80%) were satisfied with the way the course was carried out; 9 participants (20%) suggested more time for individual assignments and for practicing the modelling tool with the direct help of the course instructor. However, these participants were aware that these changes would make the course longer, and so it would be more difficult for teachers to arrange time to participate and complete the course. All 20 participants, who attended the follow-up meeting, agreed that the ICT in IBSE try-out should be definitely a compulsory part of the course. The try-out

\(^5\) For example, the Young Physicists’ Tournament: [http://iypt.org/Home](http://iypt.org/Home)

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stimulated the transfer from the operational skills of the ICT tools towards the procedural and pedagogical skills of using the tools in the classroom. However, the try-out was not necessary between Session 5 and the final defence; it could be in between Sessions 3, 4, 5.

b) Discussion

The majority of the participants were motivated and able to continue studying the ICT tools and to try out more ICT and/or IBSE lessons after the course. Their high motivation right after the course was sustained after a relatively long time (0.5 to 1.5 years), although the school conditions for the ICT in IBSE teaching were not favourable yet. In comparison with the data-logging and video-measurement tools, the participants were less confident with the modelling tool and used it less often in regular teaching. This reflects the complex nature of the modelling tool, and this matches with the fact that the modelling tool is not part of the science curriculum in Slovakia and is rarely integrated in science lessons. As long as it is not on the school tests and university entrance examinations, it will only be used by a small number of innovative teachers. In addition, the proportion of the participants who taught ICT in IBSE lessons after the course (36% of N=44) was much less than the percentage of the participants who taught lessons using the data-logging tool (73% of N=44) and the video-measurement tool (53% of N=44). This shows that the participants were quite confident in handling the ICT tools, but less confident in applying these tools in IBSE lessons.

c) Recommendations

For the future optimisation of the course, we would make the ICT in IBSE try-out a formal requirement to complete the course, considering that 20 out of 27 Cycle-2 participants could complete the try-out and they appreciated its benefits. Additionally, the try-outs could begin earlier up to the participants, for example after Sessions 2 if it concerns the data-logging tool.

5.6 Final conclusions and discussion of the chapter

In the Slovak case study, we first explored the Slovak context, and based on this exploration, we clarified the expected attainment levels of the four objectives of the Slovak course. After that, we operationalised the four pedagogical principles in the Slovak course scenario, using the support materials with respect to these expected attainment levels. In this section, we finally conclude and discuss the attainment of the four objectives of the ICT in IBSE course (Section 5.6.1), the validity of the four pedagogical principles and the support materials (Section 5.6.2), and the transferability of the ICT in IBSE course in the Slovak context (Section 5.6.3).

5.6.1 Conclusions and discussion about effectiveness of the Slovak ICT in IBSE course

a) About the awareness objective

The awareness objective: participants become aware of educational benefits of the ICT tools in science education.

Expected attainment level: after the course, the Slovak participants could enumerate one or two relevant benefits of each of the three ICT tools.
Referring to the data presented in Section 5.5.1, we conclude that the Slovak ICT in IBSE course achieved its awareness objective as expected. The Slovak participants after the course appreciated the benefits of all three ICT tools. This appreciation resulted in the motivation of the participants to study and apply the ICT tools further after the course (see Section 5.5.4).

b) About the ICT mastery objective

The ICT mastery objective: participants master skills to operate the ICT tool.

Expected attainment level: after the course, most Slovak participants could achieve basic Coach skills with all three ICT tools and reach the creator-user level for their specialised tool.

Section 5.5.2 presented the data about the participants’ ICT mastery from the assignment report, the pre- and post-course questionnaires, the computer test, and the course instructor. These data were in line with each other and confirmed that the majority of the participants were confident and able to manipulate the three ICT tools fluently (Table 5.6) and to create their own, new Coach activities (19 out of 27) for the ICT in IBSE lesson. Furthermore, a few participants (4 to 7 out of 27) even achieved the expert level of using the ICT tools as they could successfully troubleshoot two or three out of the three test problems and regularly integrate the ICT tools in their teaching practices after the course. Therefore, we conclude that the Slovak participants did achieve basic Coach skills with all three ICT tools, and almost all reached the ICT mastery from the creator-user level to the expert level for their specialised tool. This achievement of the ICT mastery objective of the Slovak ICT in IBSE course was beyond our expectation before its implementation.

The computer performance test proved to be a relevant tool to evaluate the ICT skills. It revealed the participants’ lack of trouble-shooting experience. It also proved that the Slovak participants with the low ICT entrance already got over the threshold; they were not afraid to face the TCK problems. Within the limited test time, 23 out of 27 participants could fix at least one out of three test problems. Indeed, the ICT problem solving is not a straightforward process; it requires the teachers to have a mental model of how the ICT system works. Moreover, it demands confidence and commitment of the teachers in searching and trying out solutions. The Slovak participants partly attained this mental model and made use of it with some success. This attainment level was crucial as it enabled them to study and apply the ICT tools further after the course (see Section 5.5.4). For the future optimisation of the Slovak course, we recommend making the computer performance test as an important instrument. Used as a formative assessment instrument (see Section 5.5.2), it would make the participants aware of troubleshooting as an integral part of mastering the ICT tool.

c) About the ICT in IBSE objective

The ICT in IBSE objective: participants can design, implement, and evaluate an ICT in IBSE lesson.

Expected attainment level: within the course, the majority of the participants could operationalise in the ICT in IBSE lesson plan one or two inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7, which stimulate pupils to think back and forth between the physical and
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theoretical worlds. Additionally, about half of the participants could realise their inquiry intentions in the classroom and self-evaluate their classroom try-outs.

The data presented in Section 5.5.3 show that the majority of the participants were able a) to operationalise inquiry opportunities (M=7, SD=5) in their ICT in IBSE lesson plans, b) to implement the lesson plans faithfully, and c) to evaluate the try-outs appropriately. However, the majority of inquiry opportunities fell in categories: 2.1 to 2.3, which focus on pupils’ manipulation of equipment following the prescriptive worksheet. Among the categories which involved minds-on inquiry, only the category 3.3 (e.g. determining relationships) was intended sufficiently (25 out of 27 lesson plans); other expected categories were operationalised in a minority of the lesson plans. Considering these analyses, we conclude that the Slovak ICT in IBSE course achieved its ICT in IBSE objective to some extent, but the attainment level was not as expected. There should have been more ICT in IBSE lessons that stimulated pupils to be involved in the design of the experiment/model.

Compared to before the course, the Slovak participants gained important achievement regarding PCK of inquiry teaching. They were able to choose an appropriate topic for the ICT in IBSE lesson, align the lesson plan (incl. the Coach activity) with a particular pattern of inquiry teaching, and implement it quite faithfully. The common, suitable, and preferred patterns of the ICT in IBSE lesson for the Slovak teachers were guided discovery (15 out of 27 lessons), followed by guided inquiry (7 out of 27) and interactive demonstration (5 out of 27). Under these patterns, the participants took control of the learning process and let pupils to participate in some parts under their guidance. A relatively long time after the course (0.5 to 1.5 years), the participants were quite confident in handling the ICT tools, but much less confident in applying these tools in IBSE lessons. These reflect that traditional methods were deeply rooted in teachers’ attitudes towards pupil learning. This matches with the regular teaching in Slovak schools, in which inquiry methods are rarely used, and Slovak pupils lack experience of inquiry learning (see Section 5.1.2). On the other hand, even in countries that have emphasized inquiry objectives for decades in their curriculum, inquiry opportunities are still below expectations (e.g. The UK: Abrahams & Millar, 2008; Abrahams & Reiss, 2012; The U.S.: Tamir & Lunetta, 1981; Germann et al, 1996).

d) About the motivation objective

The motivation objective: participants are motivated to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.

Expected attainment level: right after the course, the majority of the participants devised plans to learn and apply the ICT tools further. Additionally, a relatively long time after the course (0.5 to 1.5 years), about a half of the participants actually studied the ICT tools further and tried out more ICT in IBSE lessons with pupils.

The data presented in Section 5.5.4 show that almost all Cycle-2 participants (21 out of 27) devised particular plans to learn and implement more ICT in IBSE activities in the classroom. A relatively long time after the course (0.5 to 1.5 years), the majority of the participants studied the ICT tools further on their own (77% of N=44) and taught ICT in IBSE lessons more often than they did before the course. They were interested in sustainable incorporation of ICT and IBSE and proposed an ambitious plan for this (i.e. database of the tailor-made ICT in IBSE activities and regular follow-up meeting). They looked back and still
appreciated the effects of the ICT in IBSE course on their regular teaching. Considering these analyses, we conclude that the Slovak ICT in IBSE course achieved its motivation objective to a large extent, beyond our expectation. Reasons for this, among others, are a) the participants’ ownership of learning within the course and b) their confidence and appreciation gained through developing the ICT in IBSE activity, trying it out with their pupils, and evaluating the try-out in the final defence.

Research has shown that what remains from a PD course after a relatively long time is often limited (e.g. Fullan, 1991; Joyce & Showers, 2002). The limited long-term effect can be because there are still objective obstacles for actual use of innovative ideas (e.g. ICT in IBSE teaching) in the classroom, and teachers are always busy with different duties and priorities. Meanwhile, there are not often external stimulation and support like those in the course conditions for the teachers to try out the innovative ideas. In the Slovak case study, the Slovak participants encountered this situation, but they actually continued to study ICT tools and teach ICT/IBSE lessons a relatively long time after the course. Unlike many teacher education courses, the Slovak ICT in IBSE course proved to have a positive long-term effect on the teachers and their teaching practice.

Indeed, the Slovak ICT in IBSE course provided a good start for the participants to pursue the long-term vision of the course: sustainable incorporation of ICT in IBSE in teaching practice. For sustainable use of ICT and IBSE in the classroom, the teachers need continuous support and more favourable school conditions. Whereas the school condition was not easily improved in near future, the continuous support from the Slovak teacher educators is much more likely, for example:

- Tailor-made ICT in IBSE activities, which they can modify, try out with their pupils, and then gain more PCK of ICT in IBSE teaching;
- Community of teachers based on the online forum and regular follow-up meetings, through which they can exchange ideas, experience, and materials regarding ICT and IBSE teaching;
- Possibilities to borrow hardware from the university or possibilities to carry out ICT-enhanced activities in the university laboratory;
- Extra training that focuses on development and implementation of ICT in IBSE lessons, especially the ones at bounded-inquiry and open-inquiry patterns.

These were proposed by the Slovak participants and course instructors in the follow-up meeting.

5.6.2 Conclusions and discussion about the pedagogical principles in the Slovak context

We presented and discussed the data about the implementation of the pedagogical principles and the support materials in Section 5.4. In this section, we finally conclude and discuss the validity of the pedagogical principles and the support materials in the Slovak context.

a) About the “one theory-practice cycle” principle

The one theory-practice cycle principle: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson in the classroom within the course.
The data presented in Sections 5.4.1 and 5.5.3 show that the majority of the participants (20 out of 27) could complete the complete cycle of designing, implementing, and evaluating the ICT in IBSE lessons. Importantly, the ICT in IBSE try-outs were of good quality. Furthermore, the participants appreciated the benefit of the classroom try-out and gained motivation to try out more ICT in IBSE lessons after the course (see Section 5.5.4). Therefore, we concluded that the “one theory-practice cycle” principle was implemented sufficiently, and it is valid in the Slovak context. Considering the discussion in Section 5.4.1, practical conditions for this principle to be implemented faithfully were a) the sufficient duration anticipated for the classroom try-out (i.e. 7 weeks before the final defence) and b) the start of designing the ICT in IBSE lesson plan right at the beginning of the course.

While adapting the Slovak course scenario, we considered the lack of ICT equipment in Slovak schools, so did not make the ICT in IBSE try-outs as a compulsory requirement of the course. In fact, the Slovak participants made use of a minimum facility for the ICT in IBSE try-out (e.g. a computer with Coach software installed, a beamer, and/or limited equipment). The Slovak course still ended up with a good number of the participants who could complete the ICT in IBSE try-out (20 out of 27). Moreover, the try-outs were of satisfactory quality for the TCK aspect (ICT and content knowledge). Furthermore, a relatively long time after the course (0.5 to 1.5 years), the participants were not so confident in applying the ICT tools in IBSE lessons, whereas they were able to operate the ICT tools. Therefore, for the future optimisation of the course, we would make the ICT in IBSE try-out a compulsory requirement. This change would force all participants to the level of the classroom implementation of ICT in IBSE, and so probably, they would learn and benefit more from the course.

**b) About the distributed-learning principle**

The distributed learning principle: *participants study in live sessions and carry out individual assignments in between the sessions with support materials and in consultation with the course instructor.*

The data presented in Section 5.4.2 show that the majority of the participants a) spent sufficient time outside live sessions (actual on average 16 hours versus intended 15 hours); b) used the online platform and evaluated it as very useful; and c) appreciated the distributed scenario of the course. Furthermore, the distributed-learning scenario enabled, stimulated, and supported the participants to work outside live sessions on their own pace, time, and interest so that they attained a sufficient level of ICT mastery (see Section 5.5.2) and were able to experience the ICT in IBSE teaching in the classroom. Considering these analyses, we conclude that the distributed-learning principle was implemented sufficiently, and it is valid in the Slovak context.

While adapting the Slovak course scenario, we considered the low ICT-mastery entrance level of the participants whereas we expected them to achieve the creator-user level of using the ICT tool. In particular, we intended the first and larger parts of the course (4 out of 5 live sessions and 3 out of 4 assignments) for the ICT-mastery objective. That way the participants would have sufficient time to practice basic manipulations with the ICT tools with direct support of the course instructor and each other. Additionally, the individual
assignments of developing a Coach activity from scratch would reinforce and improve their skills to operate the ICT tools. This adaptation proved to be effective as the challenging ICT-mastery objective was attained to the expected level whereas other objectives, especially the ICT in IBSE one were achieved as well.

The participants were satisfied with the formats and timing of live activities (Cycle 2). The practice of ICT skills in groups of two with the Coach support materials and the personalised support of the course instructor (Cycle 2) proved to be much more effective than the practice under the plenary step-by-step instructions (Cycle 1). This is in line with a conclusion about an innovative model for integrating technology into teacher education in Thurston, Secaras, and Levin (1997, p.390): “as much hands-on experience as possible with technology, rather than lectures and demonstrations, is critical.”

c) About the depth-first principle

In the Slovak context, we operationalised the depth-first principle in the scenario in which the Slovak participants would study the possibilities and manipulation skills of all three ICT tools and then specialise in only one tool by choice in designing and trying out the ICT in IBSE lessons. The data and discussions presented in Sections 5.4.3, 5.5.2, and 5.5.3 show that this operationalization of the depth-first principle in the Slovak course scenario proved to be relevant and effective, considering that:

- The participants at the low entrance level could achieve the sufficient ICT skills.
- The participants could master all the three tools as they expected.
- The participants could still come to a certain level of depth regarding a) the ICT in IBSE try-out within the course and b) the confidence to try out more ICT in IBSE lessons after the course.

Of 27 participants, 5 participants did not follow the one-tool specialisation in designing and implementing the ICT in IBSE lessons. It was a deviation from the principle, but it turned out interesting. The five participants combined the use of the modelling tool with one of the two other tools. This combined use was relevant to stimulate one complete inquiry process, and it was recommended by the research of Heck, Ellermeijer, and colleagues (e.g. Heck & Ellermeijer, 2009, 2014; Heck, Uylings, Kedzierska, & Ellermeijer, 2010; van Eijck, Goedhart, & Ellermeijer, 2005). The participants’ combined use of the ICT tools was apparently inspired by some Coach exemplary materials and the introductory slides about possibilities of the ICT tools. The participants’ ability to integrate the use of different ICT tools in one inquiry lesson probably resulted from the fact that they gained basic mastery for all the three tools. Considering this surprising result and the satisfactory level of the ICT-mastery attainment, for the future optimisation of the course, we would focus and stimulate the participants more on the combine use of the ICT tools for their Coach activities. The participants would appreciate more education benefits of the ICT tools, and so their sustainable and meaningful use of these tools in the classroom would be more likely.

d) About the “ownership of learning” principle

The ownership-of-learning principle: participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives.
The data presented in Section 5.4.4 show that the majority of the participants were proactive in live activities and individual assignments in pursuing their own goals with respect to the course objectives. Importantly, this initiative resulted in demonstrable outcomes regarding their awareness, skills, and motivation after the course (see Section 5.6.1). Therefore, we conclude that the ownership of learning was implemented sufficiently, and it is valid in the Slovak context.

This principle proved to match well with the diversity of the Slovak participants, concerning their mixed background, different teaching conditions, different phases of the teaching career trajectory, and different attitudes towards professional learning. We dealt with this diversity by giving the participants opportunities to tailor and pursue their learning path and to make their own choices within the particular framework. Additionally, in the Slovak case study, we made use of many contact hours in the live sessions to accommodate differences among participants’ ICT mastery and learning pace through the personalised and direct support. Therefore, no participants were left behind, and we were able to bring almost all participants to similar, appropriate level of ICT mastery before they made their own choices regarding their ICT in IBSE lessons.

e) About the support materials

The data presented in Section 5.4.5 show that the participants appreciated and evaluated the support materials as very useful for the Slovak ICT in IBSE course. Considering the faithful and effective implementation of the course, the support materials proved to be necessary and useful for the participants to learn in the distributed scenario, to master all three ICT tools, to design the ICT in IBSE lesson, and to pursue their self-tailored learning process within the course scenario.

For the Slovak course, we used the ESTABLISH exemplary lessons in addition to the support materials for the general design of the ICT in IBSE course. Together with the Coach exemplary activities, these extra lesson materials proved to be relevant and important as well. This shows that for actual implementation of innovative ICT in IBSE teaching, the teachers really need well-designed exemplary lesson materials; especially the materials that were tailored to fit the local curriculum (see Section 5.5.4). Therefore, for the future optimisation of the Slovak ICT in IBSE course, we would select and use more tailor-made ICT in IBSE exemplary materials. Considering that the participants themselves did not have much experience with inquiry strategies, especially bounded inquiry and open inquiry, we would select, design, and use more ICT in IBSE exemplary materials that are aligned with these two inquiry patterns.

5.6.3 Transferability of the ICT in IBSE course in the Slovak context

The Slovak context had specific characteristics, which were remarkably different with those of the Dutch context. In particular, the Slovak participants were teachers with diverse teaching experiences, whereas the Dutch participants were student teachers. Before the course, the Slovak participants had very little experience with the ICT tools and lacked practical experience with inquiry teaching with or without ICT (the Dutch participants having more experience with the ICT tools). Meanwhile, the curriculum reform, which has been implemented since 2008, required them to be able to handle the ICT tools, to develop IBSE
materials incorporating ICT, and to use these materials in the classroom. These were indeed specific challenges for the Slovak ICT in IBSE course, which was restricted to five live sessions, equivalent to 25 contact hours. In this context, to what extent was the course transferable?

a) Adaptations of the course objectives and the pedagogical principles

Following demands from the schools, the ICT-mastery objective of the Slovak course was extended to all of the three ICT tools. The Slovak participants were expected to achieve basic skills with all three tools and to attain the creator-user level for a specialised tool (this expectation was higher than that for the Dutch participants). Accordingly, the Slovak participants specialised in one tool to design the ICT in IBSE lesson after having already acquired basic skills with all three tools (adaptation of the depth-first principle). Furthermore, taking the low ICT entrance of the Slovak participants into account, we allocated 4 out of 5 live sessions and 3 out of 4 individual assignments for them to master the expected ICT skills. In other words, we focused in the first and larger parts of the course on the ICT-mastery objective (adaptation of the distributed-learning principle). Additionally, we encouraged the Slovak participants to try out their ICT in IBSE lesson plans with pupils, but did not make the ICT in IBSE try-out as a compulsory requirement of the course, considering the lack of ICT equipment in Slovak schools (adaptation of the “one theory-practice cycle” principle).

b) Strengths of the Slovak ICT in IBSE course

The Slovak ICT in IBSE course was successful in bringing its participants from the non-user level to the creator-user and expert levels of using the ICT tool. The Slovak participants did achieve basic ICT skills with all of the three tools, as they desired. Compared with the Dutch participants, the Slovak participants attained a higher level of ICT mastery. This shows effectiveness of the many more contact hours with direct, personalised support scheduled for the ICT-mastery objective in a) compensating for the low ICT entrance of the Slovak participants and b) enabling them to achieve the expected ICT mastery. Although spending much time for studying all three ICT tools, the Slovak participants were still able to reach to a certain level of depth. In particular, although the try-out was not compulsory, around three fourths of the participants completed the ICT in IBSE try-out. These try-outs were of satisfactory quality for the TCK aspect (ICT and content knowledge). This suggests us to make the ICT in IBSE try-out a compulsory requirement for future optimisation of the course.

c) Weaknesses of the Slovak ICT in IBSE course

The Slovak ICT in IBSE course achieved its ICT in IBSE objective to some extent, but the IBSE attainment level was not as expected. There should have been more ICT in IBSE try-outs that stimulated pupils to be involved in the design of the experiment/model (like in the Dutch case). The Slovak participants focused too much on pupils’ execution of experiments or models (manipulation of equipment and software). Most Slovak participants intended to take control over the entire classroom activity through plenary systematic explanations and/or prescriptive worksheets for the group work (patterns of interactive demonstration and guided discovery). In contrast, for half of the Dutch ICT in IBSE lesson plans, pupils were provided with more participation and independence in more-open inquiry
patterns (i.e. guided inquiry, bounded inquiry, and open inquiry) (compare Figure 5.7 and Figure 4.15 in Chapter 4). These are persistent problems, which has been discussed in the literature on laboratory teaching for a long time. The Slovak ICT in IBSE course was not successful in supporting its participants to get through these problems yet. To improve this weakness, more time must be scheduled for the ICT in IBSE objective by 1) proposing a longer course or 2) redistributing the learning time between the first part for mastering the ICT tools (the ICT-mastery objective) and the second part for designing and trying out the ICT in IBSE lesson (the ICT in IBSE objective). Considering our experience with the Dutch course, with more time for the second part, in-depth exercises and discussions on minds-on inquiry with back-and-forth thinking between the worlds of ideas and phenomena should be added, and the ICT in IBSE lesson plan should be commented by the course instructor and then improved before the classroom try-out.

d) Final remarks

The adaptations to the Slovak context proved to be very necessary to make the Slovak ICT in IBSE course viable and effective and fit the national in-service accreditation requirements. Our research data show that we achieved the course objectives in Slovakia, except that for the ICT in IBSE part there was still much room for improvement. These results confirmed external validity of the pedagogical principles and transferability of the ICT in IBSE course in the Slovak context.

Based on these effective adaptations, we learnt that with regard to adaptation of the course design in a different context, the “one theory-practice cycle” principle should not be changed. Instead, the depth-first principle and distributed-learning principle can be adjusted to some extent to the entrance level and other characteristics of the participants and the scheduling requirement. The adjustment with these two principles makes the first flexible phase of the course design, which can be lengthened and shortened in order to distribute the learning time and focus the participant efforts on the crucial objective of the course (i.e. the Slovak case: ICT-mastery objective and the Dutch case: ICT in IBSE objective).
Chapter 6 Adaptation, implementation, and evaluation of the Vietnamese ICT in IBSE course

This chapter presents the adaptation, implementation, and evaluation of the ICT in IBSE course in Vietnam. Section 6.1 explains why the Vietnamese context was chosen for a case study of this research project and clarifies adjustments made for this specific context. The adjustments concerned the expected attainment levels of the course objectives and the operationalization of the pedagogical principles in the course scenario. Section 6.2 presents the concrete scenario of the Vietnamese course and the support materials. In Section 6.3, we clarify how we adapted the evaluation framework and instruments, which were described in Chapter 3. We present and discuss the results of the Vietnamese case study in Sections 6.4 and 6.5. In Section 6.6, we draw conclusions about the attainment of the course objectives and the validity of the pedagogical principles in the Vietnamese educational and cultural context, followed by discussions about transferability of the ICT in IBSE course and about what affordances and limitations such context has for the course design and IBSE application.

6.1 Background, context, and methodology

6.1.1 Summary of the explorative phase of the research project

*How does one introduce IBSE in an educational system?* The literature (Fullan, 2007; Supovitz & Turner, 2000) clearly shows that the teacher is the most important factor in introducing and incorporating IBSE in schools. Therefore, we propose to do this through teacher education, and that is the reason for the development of our ICT in IBSE course. In the explorative phase of the present research, we defined a) the general design of the ICT in IBSE course, including the four course objectives, the four pedagogical principles, and the support materials and b) the evaluation framework plus instruments for data collection and analysis (Chapters 2 and 3). In the research phase, we aimed to test effectiveness of the ICT in IBSE course (attainment of the objectives), validity of the pedagogical principles, and transferability of the course design through case studies with different teacher groups in different countries. In addition to the study with Dutch student teachers (Chapter 4) and the study with Slovak experienced teachers (Chapter 5), we explored opportunities for another case study in another considerably different context.

We had an opportunity to implement the ICT in IBSE course within the Master programme on physics education offered by Hanoi National University of Education (HNUE), Vietnam. Participants of this programme are a mix of Vietnamese experienced teachers and fresh teacher-education graduates, who continue straight from Bachelor to Master. The Vietnamese version of the ICT in IBSE course had to be condensed in five weeks with many contact hours to be scheduled (i.e. 30 to 60 hours) (the Dutch and Slovak versions had much less contact hours, but these could be spread over much longer periods). Additionally, Vietnamese schools, teachers, and pupils have almost no ICT and IBSE experience. This partly results from Vietnamese hierarchical culture, which is embodied in the educational system (Le, 2001). For many years, Vietnamese society has perceived and accepted a dominant role of teachers in the school’s learning environment. On the pupils’
side, Vietnamese pupils generally behave disciplined in the classroom: listening to teachers, taking notes, and following whatever teachers assign (T.T. Nguyen, 2005). However, they are often hesitant to ask questions, to share their own viewpoints, and to disagree with teachers during classroom discussions (Hang, Meijer, Bulte, and Pilot, 2015, 2016). On the teacher’s side, Vietnamese teachers are often afraid of not teaching enough subject matter, afraid of not reacting to pupils’ questions correctly, and afraid of not able to manage unexpected behaviours of pupils (L. Nguyen, 2014). Therefore, Vietnamese teachers tend to exercise strict control over classroom activities; pupils’ learning from mistakes is not encouraged; and so the classroom in Vietnam is still much teacher-centred.

This situation in Vietnam provided us with an interesting and relevant option to a) try out the ICT in IBSE course once more and b) conduct another transferability test of whether the course design and principles hold in a situation where the participants’ background, the scheduling requirements, and the local educational and cultural system are remarkably different. Especially, the Vietnamese classroom culture seems unfavourable to introducing IBSE with or without ICT. Therefore, Vietnam was an interesting choice for the third case study of the ICT in IBSE course. We collaborated with teacher educators of HNUE to adapt and teach the Vietnamese ICT in IBSE course and conduct the Vietnamese case study, which addressed two general research questions for the transferability test:

A. To what extent were the four pedagogical principles implemented in the Vietnamese context as intended?

B. To what extent did the Vietnamese ICT in IBSE course achieve its four objectives?

Furthermore, the case study concerned a specific question for the Vietnamese case:

C. What are the challenges and potential solutions to the application of IBSE in a hierarchical education culture?

According to the research design, the Vietnamese case study was limited to only one cycle. Because it was conducted at the end of the research phase, we could make use of our experiences and understandings gained through the implementation, evaluation, and optimisation of the ICT in IBSE course in the Netherlands. In the following sub-sections, we present the Vietnamese context in more detail: characteristics of the Vietnamese participants, their teaching conditions, and the boundary conditions of the ICT in IBSE course within the Master programme. In order to explore these background data, we analysed the programme, interviewed the Vietnamese local course instructor, and administered the pre-course questionnaire to the participants. Moreover, collection and analysis of data from other sources (e.g. classroom observations, communication records) during the course implementation generated additional descriptive background data.

6.1.2 The Vietnamese context and boundary conditions of the Vietnamese course

a) The Vietnamese context

To become a teacher, one needs to graduate from a Bachelor programme of teacher education offered by 14 Vietnamese universities of education. With a Bachelor degree, a graduate can be employed as a full-time teacher by secondary schools (L. Nguyen, 2014). About continuous professional development (PD), Vietnamese teachers are responsible for
developing their individual PD and participating in short-term PD activities (e.g. observing the teaching of fellow teachers, participating in workshops for teachers, and taking part in teaching competitions). These short-term PD activities are scheduled for at least 120 hours per academic year and offered and coordinated by schools, the provincial Departments of Education and Training, and/or the Ministry of Education and Training of Vietnam (MoET) (T.V. Ho, Nakamori, B.T. Ho, & S.D. Ho, 2014). Furthermore, Vietnamese teachers are supported to enrol in a two-year, full-time, university-based Master programme on subject-specific pedagogy (e.g. mathematics education, physics education, geography education). According to the national regulations by MoET (the circular number 15/2014/TT-BGDĐT), teachers with at least two years of teaching experience are qualified for the Master-programme entrance examination on foreign language and subject-specific knowledge. Fresh graduates who have completed their Bachelor teacher education programme with good study results can be also accepted to take the entrance examination. Master students, who are already employed as full-time teachers, can keep their job without teaching (in case the school is very far from the university) or teach a reduced load.

Of the 14 universities of education in Vietnam, eight universities offer the Master programme on physics education and recruit candidates nationwide with the same entrance criteria based on the MoET’s regulations. The ICT in IBSE course was adapted and implemented within the Master programme on physics education at HNUE. All 22 master students in the academic year 2014 – 2015 took part in the course. There is no reason to suspect that this group of 22 master students is not representative for the total population of Vietnamese master students in physics education.

According to university regulations, the first half of the Master programme on physics education at HNUE includes courses on physics, and the second half is devoted to courses on physics education, followed by a Master's research project. Courses are condensed and scheduled in blocks of five weeks; in every block, two courses are taught in parallel. The ICT in IBSE course was integrated in the programme as a compulsory and final physics-education course. The programme has no components or assignments in schools, but the research project of each master student must contain a classroom try-out of research ideas or educational products. Because of having course sessions on campus on almost every day of the week, master students often live in the university dormitory or apartments nearby. This establishes a close learning community in which master students discuss their coursework, do home assignments together, and learn from each other.

From 2016, Vietnam will prepare for an educational innovation across all levels of primary and secondary education. The curriculum reform will place more emphasis on inquiry skills and ICT application in physics education among comprehensive changes. This results in a huge demand for (re)educating teachers nationwide, which is considered by MoET as one of the most important factors to ensure the success of the reform (MoET, 2011). According to the Vietnamese participants of the ICT in IBSE course, incorporation of ICT and IBSE in physics education would be challenging; the course objectives were in line with this innovation, so through the course, they could prepare for such challenging innovation. Consequently, the incentive to participate in the course was high.
b) Characteristics of the Vietnamese participants

Of 22 Vietnamese participants, 5 participants (23%) came straight from a Bachelor teacher-education programme. These participants gained just little teaching experience through the teaching practicum in the school for 8 to 10 weeks (L. Nguyen, 2014). The other 17 participants (77%) had taught for 2 to 9 years (M=5, SD=2). Of these participants, 10 participants stopped teaching for participating the full-time Master programme, and 7 others (32% of N=22) were still teaching a few lessons per week.

Through a previous Master course, the participants studied the theory of data logging with sensors, but they had not practiced with any data-logging tools for school physics yet. They had practiced manipulation skills with video measurement software that had limited features (e.g. no authoring facilities) in comparison with Coach. They were not familiar with dynamical modelling and modelling tools. The three Coach tools were new to the Vietnamese participants. According to their responses to the pre-course questionnaire, they had not had any experience of teaching with the ICT tools in the classroom.

In previous Master courses, the theory of IBSE had been taught, and the focus was on inquiry process that is a) guided by sequential, well-prepared questions and tasks and b) based on demonstrations of phenomena and concepts in the laboratory activities, and c) aimed at concept development and subject-specific goals scheduled in the school physics syllabus. The participants got used to designing IBSE lesson plans with this focus, implementing such lesson plans with peers as learners, and then receiving feedback from course instructors. The feedback and discussion often concerned whether pupils could be engaged in (partly) formulating questions and hypotheses; designing and executing experiments; and explaining experiment results. However, as most participants reported, they lacked practical experience of inquiry teaching in the classroom. Within the Master programme, the ICT in IBSE course was the first and only course that let the Master students to try out their pedagogical ideas and learn from this.

c) Teaching conditions of the Vietnamese participants

Via the follow-up questionnaire, the participants evaluated their teaching conditions for application of ICT and IBSE as insufficient (1.2 to 2.6 of the 5-point scale, Figure 6.1). The competitive entrance examination to universities dominates the entire educational system. It mainly requires pupils to recall discrete facts, concepts, and theories and to solve standardised theoretical problems. This makes the de-facto physics curriculum in Vietnam theoretical and crowded. Vietnamese teachers are pressed to teach the complete contents included in the examination syllabus and constrained to non-IBSE teaching methods. These methods focus on pupils memorising theories and exercising pragmatic strategies and tricks to solve theoretical problems included in exemplary-test materials (T.T. Nguyen, 2005). Although included in the intended curriculum, laboratory activities and demonstrations are often skipped, due to time-consuming preparation and the priority given to the theoretical examinations (L. Nguyen, 2014). As a result, Vietnamese pupils have almost no experience with inquiry-based learning and laboratory activities. These routine conditions potentially hinder introduction of IBSE in Vietnamese schools.
8.1. Availability of computers, software, and sensors
8.2. Opportunities within the school curriculum
8.3. Pupils’ experience with inquiry based learning
8.4. Pupils’ experience in using ICT tools
8.5. Encouragement by the school management
8.6. Support from colleagues

Figure 6.1. The Vietnamese participants’ evaluation of their teaching conditions for application of ICT and IBSE in the classroom (N=22) (5-point scale, 1=poor, 5=excellent).

ICT tools for data logging with sensors, video measurement, and dynamical modelling are not available in Vietnamese schools yet. Consequently, Vietnamese pupils have no experience in using the ICT tools (Figure 6.1). In general, Vietnamese schools have minimum laboratory equipment for fundamental experiments included in the national textbook and limited computers and beamers for lessons using multimedia and information technology. The laboratory and ICT facilities can only accommodate half of a normal class of 35 to 45 pupils.

d) Time constraints as boundary conditions of the Vietnamese course

According to the regulations of the Master programme, total 60 study hours were scheduled within five weeks for the ICT in IBSE course. We could allocate from two to four live sessions per week, equivalent to 30 to 60 contact hours in total. In the meantime, the participants had to a) attend another parallel 60-hour course with many home assignments, b) prepare for examinations of the two previous courses, and c) write a research proposal for the master thesis. Additionally, seven participants (out of 22) still had to teach. Consequently, the participants would have limited time for individual assignments in between live sessions of the ICT in IBSE course.

The number of two to four live sessions per week (three hours each) was expected to be sufficient for the participants to master the ICT tools and design the ICT in IBSE lesson plan within the first three weeks of the course. However, the remaining two weeks would be very constrained, considering that insufficient school conditions would probably cause barriers for the participants to arrange and implement the ICT in IBSE lessons with pupils. For example, many participants (15 out of 22) did not teach while studying the Master programme, so it took them time to search for secondary schools, teachers, and pupils who were willing to cooperate for the ICT in IBSE try-out. It would be difficult for the participants to find relevant topics for the ICT in IBSE lesson within the physics syllabus (three physics lessons per week), because it was crowded with many subject-specific goals to attain. Furthermore, the participants had to do much preparation and logistics by themselves for the ICT in IBSE try-out such as exploring the pupils’ prior knowledge, installing the Coach software in the school, and introducing pupils to Coach in advance.
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6.1.3 Expected attainment levels of the Vietnamese course objectives

Taking into account the characteristics of the Vietnamese participants, their teaching conditions, and the time-constraint conditions of the Vietnamese course (see Section 6.1.2), we adapted the expected attainment levels of the four course objectives. These objectives were described in Chapter 2 as follows:

1. **Awareness objective**: Participants become aware of educational benefits of the ICT tools.

2. **ICT mastery objective**: Participants master skills to operate the ICT tool.

3. **ICT in IBSE objective**: Participants can design, implement, and evaluate an ICT in IBSE lesson.

4. **Motivation objective**: Participants are motivated to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.

In the Vietnamese context, the participants had to be able to demonstrate and explain ICT-enhanced experimentation/modelling activities clearly to pupils and/or guide pupils to manipulate the ICT tools explicitly. Pupils had no experience with the ICT tools, and no one else in the school could support the participants and pupils in using the tools. Furthermore, for future incorporation of the ICT tools, the participants needed to be able to adapt and develop ICT in IBSE materials that fit the local physics curriculum and their teaching conditions. Therefore, about the awareness objective, we expected that after the course, the Vietnamese participants could enumerate one or two relevant benefits of each of the three ICT tools in physics education. About the ICT mastery objective, referring to the predefined attainment levels in Chapter 3, Section 3.4.3, we expected the Vietnamese participants to reach the adaptor-user level or the creator-user level for their specialised tool. At these levels, participants should manipulate the Coach tool fluently, and they should be able to adapt or create Coach activities for their ICT in IBSE lessons.

The Vietnamese participants lacked teaching experience with pupil investigations and with the ICT tool. In addition, for Vietnamese pupils, inquiry learning with and without ICT is far beyond what they are used to in their regular class. Other teaching conditions in Vietnamese schools such as curriculum time, preparation time, and availability of ICT are/were not yet sufficient for incorporation of ICT in IBSE. Therefore, about the ICT in IBSE objective, referring to the predefined attainment levels in Chapter 3, Section 3.4.3, concerning the ability to design, we expected that the participants would be able to operationalise most of their inquiry objectives as inquiry opportunities in the lesson plan. Importantly, we expected to see in a half of the lesson plans one or two inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7 to be operationalised. Concerning the ability to implement, we expected about half of inquiry opportunities (specified in lesson plans) to be realised in the classroom. Concerning the ability to self-evaluate, we expected that about a half of the participants would be able to a) evaluate achievement of their lesson’s inquiry objectives, b) indicate what did not go as intended and why, and c) suggest relevant changes of the lesson plan for future implementation.

About the motivation objective, referring to the predefined attainment levels in Chapter 3, Section 3.4.3, we expected that the majority of the participants would achieve at
least Level 2: right after the course, they devised plans to learn and apply the ICT tools further. We hoped that about a half of the participants would achieve Level 3: relatively long time after the course (e.g. 0.5 years), they had actually studied the ICT tools further and had tried out more ICT in IBSE lessons with pupils.

### 6.1.4 Operationalization of pedagogical principles in the Vietnamese course

Taking into account the expected attainment levels of the objectives and the Vietnamese context, we operationalised the pedagogical principles (see Chapter 2, Section 2.4.2) in the Vietnamese course scenario. In particular, regarding the "one theory-practice cycle" principle, the participants had to design and try out an ICT in IBSE lesson with pupils and then self-evaluate the try-out as a compulsory and key requirement to complete the course. Considering the unfavourable conditions in Vietnamese schools (see Section 6.1.2), the participants were allowed to design and try out their ICT in IBSE lessons as teacher-led demonstrations. This requires just the minimum facility: a computer with the Coach software installed, a beamer, and/or limited equipment, whereas pupils can still participate in designing experiments/models and interpreting the results. In addition, the participants were also allowed to conduct the ICT in IBSE try-out with one-half of a class in a regular lesson or with 4 to 6 pupil volunteers outside regular lessons.

The distributed-learning principle concerned the division of the activities and study time between live sessions and individual assignments outside these live sessions. In the Vietnamese context, we could allocate much time on campus (i.e. 30 to 60 hours), but we could not spread the course duration longer than five weeks in order for the participants to have more time at home or in schools doing individual assignments. Taking advantage of the ample contact time, we scheduled most of the individual assignments on campus. In particular, the participants work on their assignments individually in the course room and consulted the course instructors and peers as needed. With the direct help of the course instructors and peers, the participants would get over initial hurdles in studying new ICT tools swiftly, and they would be able to troubleshoot their problems in adapting or developing the Coach activity for the ICT in IBSE lesson. Moreover, we organised specific live sessions for participants to report their Coach activity and their ICT in IBSE lesson plans and to get direct feedback for improvement before the classroom try-out. Additionally, we scheduled many more contact hours in the first two weeks (so fewer hours in the remaining three weeks) for the participants to master the ICT skills soon and optimise the lesson plan timely for the classroom try-out in the last two weeks.

Regarding the depth-first principle, the participants’ in-depth learning involved two aspects. First, the participants learnt not only to manipulate but also to apply the tool in ICT in IBSE lessons; this in-depth process potentially includes the five stages:

- **Stage 1.** Studying possibilities of the ICT tools
- **Stage 2.** Mastering skills to operate the ICT tool
- **Stage 3.** Designing the ICT in IBSE lesson that makes use of the ICT tool
- **Stage 4.** Teaching the ICT in IBSE lesson with the ICT tool
- **Stage 5.** Evaluating the ICT in IBSE try-out with the ICT tool
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Second, the participants studied all three tools at the first stage(s) (acquaintance phase) and then specialised in one of the three ICT tools (by choice) at the remaining stages (specialisation phase). Considering the “ICT mastery” and “ICT in IBSE” objectives, the participants were expected to master sufficient ICT skills quickly in order to start early designing the lesson and dealing with organisational barriers for the classroom try-outs within the limited time: the last 2 weeks out of the total 5 weeks of the course. This expectation was rather difficult to realise, because the ICT-mastery entrance level of the Vietnamese participants was low. Therefore, for the Vietnamese ICT in IBSE course, the one-tool specialisation started soon after Stage 1.

Like in the Dutch and Slovak versions of the ICT in IBSE course, we operationalised the “ownership of learning” principle in the Vietnamese version in concrete ways:

• the one-tool specialisation by choice;
• the freedom to choose which topic the ICT in IBSE lesson would be about, which inquiry components to focus on, and whether to try out in a complete class, in half a class, or in a group of 4 to 6 volunteer pupils;
• the focus on individual and group work rather than plenary activities.

This operationalization would enable the course to accommodate the participants with different interest and teaching experience and empower them to deal with insufficient school conditions for the ICT in IBSE try-out.

6.2 Scenario of the Vietnamese ICT in IBSE course

6.2.1 Overview of the Vietnamese course scenario

Of the total 60 study hours within the five weeks, 30 hours were scheduled for seven live sessions: the first four sessions took place in a half day (3 hours) each and the last three sessions in two half days (6 hours) each. The remaining 30 hours outside live sessions were anticipated for the individual assignments, including 21 hours on campus for participants to practice ICT skills and design the ICT in IBSE lesson plans and 9 hours in schools for participants to arrange and try out their lesson plans (Table 6.1). The participants were encouraged to do the individual assignments on campus, but they did not have to spend all 21 hours (seven half days). They could do assignments at home and/or spend more hours in schools to arrange and conduct the ICT in IBSE try-out.

According the regulations of the Master programme, the participants’ learning outcome had to be measured and graded. If the participants achieved the final grade that was more than 5 out of 10 points, then they would pass the course and collect the credit. The grading was based on the evaluation of the ICT-mastery and ICT in IBSE objectives. The final grade included three components: a) the grade of the ICT in IBSE lesson plan, which was evaluated in Session 6, b) the grade of the ICT in IBSE try-out, which was evaluated in Session 7, and c) the grade of the computer performance test at the end of Session 7. Already in Session 1, we explicitly clarified these evaluation components with concrete criteria and emphasised Sessions 6 and 7 as assessment sessions. The detailed information about assessment would help the participants to focus on the learning objectives.
Table 6.1. Summary of intended activities in live sessions and requirements for individual assignments of the Vietnamese ICT in IBSE course.

<table>
<thead>
<tr>
<th>Week</th>
<th>Scenario</th>
<th>Time frame*</th>
<th>Participants’ activities</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Week 1</td>
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</tr>
<tr>
<td><strong>Session 1</strong></td>
<td>(a half day)</td>
<td>3 hours</td>
<td>• Listening to the introduction about the data-logging tool</td>
<td>Plenary</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Practising the introductory data-logging activities</td>
<td>In pairs</td>
</tr>
<tr>
<td><strong>Session 2</strong></td>
<td>(a half day)</td>
<td>3 hours</td>
<td>• Listening to the introduction about the video-measurement tool</td>
<td>Plenary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Practising the introductory video-measurement activities</td>
<td>In pairs</td>
</tr>
<tr>
<td><strong>Session 3</strong></td>
<td>(a half day)</td>
<td>3 hours</td>
<td>• Listening to the introduction about the modelling tool</td>
<td>Plenary</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Practising the introductory modelling activities</td>
<td>In pairs</td>
</tr>
<tr>
<td><strong>Session 4</strong></td>
<td>(a half day)</td>
<td>3 hours</td>
<td>• Discussing how to design an ICT in IBSE lesson</td>
<td>Plenary</td>
</tr>
<tr>
<td>Assignment 1</td>
<td>(four half days on campus)</td>
<td>5 days</td>
<td>• Choosing one of the three ICT tools and practising manipulation skills through the tutorial and exemplary Coach activities</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Adapting/creating the Coach activity for the ICT in IBSE lesson</td>
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<td></td>
<td></td>
<td></td>
<td>• Writing a draft version of the ICT in IBSE lesson plan</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Session 5</strong></td>
<td>(two half days)</td>
<td>6 hours</td>
<td>• Reporting the Coach activity and the draft plan of the ICT in IBSE lesson</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Getting feedback for improvement</td>
<td>reports in the plenary session</td>
</tr>
<tr>
<td>Assignment 2</td>
<td>(three half days on campus)</td>
<td>3 days</td>
<td>• Optimising the Coach activity and learning scenario for the ICT in IBSE lesson plan</td>
<td>Individual</td>
</tr>
<tr>
<td>Week 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Session 6</strong></td>
<td>(two half days)</td>
<td>6 hours</td>
<td>• Reporting the final, entire version of the ICT in IBSE lesson plan to the course instructors and peers</td>
<td>Individual</td>
</tr>
<tr>
<td>Assessment 1</td>
<td></td>
<td></td>
<td></td>
<td>reports in the plenary session</td>
</tr>
<tr>
<td>Assignment 3</td>
<td>(9 hours in schools)</td>
<td>15 days</td>
<td>• Arranging the ICT in IBSE try-out</td>
<td>Individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Conducting the try-out</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Self-evaluating the try-out</td>
<td></td>
</tr>
<tr>
<td>Week 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Session 7</strong></td>
<td>(two half days)</td>
<td>6 hours</td>
<td>• Presenting and self-evaluating the ICT in IBSE try-out to the course instructors and peers</td>
<td>Individual</td>
</tr>
<tr>
<td>Assessment 2</td>
<td></td>
<td></td>
<td></td>
<td>reports in the plenary session</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Taking the computer performance test</td>
<td>Individual</td>
</tr>
</tbody>
</table>

(*) “Hours” mean actual hours of work within the course. “Days” indicate the period during which time would be spent on the course assignments.
The course was taught by two course instructors: the researcher (PhD candidate) and the HNUE teacher educator who has rich research and teaching experience in physics education, ICT, and IBSE. The researcher was in charge of the ICT part, and the Vietnamese colleague was responsible for the IBSE and ICT in IBSE part of the course. The two instructors coordinated the course together. In Sessions 6 and 7, an extra one or two HNUE teacher educator(s) were involved in giving feedback to the participants’ presentations on the ICT in IBSE lesson plans and try-outs and then evaluating the lesson design and implementation. Another member of the research team (a PhD supervisor) came for observation of the final part of the course. He observed Session 6 and attended 9 out of 22 ICT in IBSE try-outs. Regarding the material condition for the course, we borrowed the Coach sensors and interfaces from CMA and received CMA’s permission to install the Coach software on participants’ and schools’ computers.

6.2.2 Support materials and personalised support

In Chapter 3, Section 3.1.4, we described the following support materials for the general design of the ICT in IBSE course:

- **S**: Introductory slides for the ICT tools and possibilities of using these tools
- **C1**: Coach introductory activities to illustrate the Coach platform
- **C2**: Coach tutorial materials to practice manipulation skills with the Coach tool
- **C3**: Coach exemplary materials about how to integrate the Coach tool in inquiry-based science lessons
- **F1**: Form 1 for the assignment report on practice with the ICT tool
- **F2**: Form 2 for the lesson plan of the ICT in IBSE lesson
- **F3**: Form 3 for participants’ self-evaluation of the ICT in IBSE try-out

These support materials were translated into Vietnamese and used for the Vietnamese ICT in IBSE course.

For the general design of the course, the online platform was used for participants to access the support materials and to consult the course instructor. For the Vietnamese course, the online platform was not used, because individual participants had many contact hours with the course instructors (i.e. live sessions and assignments on campus) to get direct and personalised support and support materials.

6.2.3 Programme for live sessions and requirement for individual assignments

In the first half of Week 1, each of Sessions 1, 2, and 3 was devoted for the participants to become aware of the possibilities of one of the three tools: data logging, video measurement, and dynamical modelling. In each session, the course instructor first introduced basic concepts and possibilities of a particular ICT tool through the introductory slides (S) and demonstrations with the Coach software. The participants then acquainted themselves with that tool through practicing the Coach introductory activities (C1). In Session 4, the course instructor elicited what the participants already knew about IBSE and compared this to the ICT in IBSE framework used for the course. Next, the guidelines, criteria, and forms for designing, implementing, and evaluating an ICT in IBSE lesson were given and discussed among the participants and the course instructor.

Assignment 1 was scheduled for four half days on campus in the second half of Week 1 and the first half of Week 2. It required the individual participants to specialise in one of the
three ICT tools by choice and practise their chosen ICT tool to acquire basic manipulation skills, using the Coach tutorial and exemplary activities (C2, C3). They were required to write a report about what they learnt and what they struggled with, using Form 1 (F1). After that, the participants had to choose and adapt a Coach activity or create a new Coach activity for the ICT in IBSE lesson. They were required to make a draft version of the ICT in IBSE lesson plan, using Form 2 (F2). The participants were encouraged to do Assignment 1 on campus (four half days) (Figure 6.2a) and consult each other and the course instructor when encountering difficulties. Doing Assignment 1 on campus was also a practical solution for the problem that the participants specialising in the data logging tool did not have the Coach sensor and interface at home or in schools to practice.

In Session 5, each participant one after another reported her or his Coach activity and draft plan of the ICT in IBSE lesson in a plenary presentation for 10 to 15 minutes. After that, she or he received feedback from the course instructors and peers for improvement. Assignment 2 (three half days on campus in the second half of Week 2) required the participants to optimise their ICT in IBSE lesson plan and finalise lesson materials (e.g. PowerPoint slides, pupil worksheet). The final lesson plan was reported (Figure 6.2b) and formally evaluated in Session 6 (two half days in the first half of Week 3).

![Figure 6.2. Photographs of Vietnamese participants' activities in chronological order: a) practising manipulation skills with Coach on campus, b) reporting the ICT in IBSE lesson plan before the try-out, c) trying out the lesson with pupils, and d) reporting back in an assessment session.](image)

Within the 15 days after Session 6 (the second half of Week 3, entire Week 4, and the first half of Week 5), 9 hours were anticipated for Assignment 3, which required the participants to try out their ICT in IBSE lesson plans with pupils. Next, they had to write a
self-evaluation report on their ICT in IBSE try-out, using Form 3 (F3). Considering the potential organisational obstacles in schools, the participants were encouraged right at the beginning of the course to contact schoolteachers and pupils for arrangement of the ICT in IBSE try-out. Additionally, the participants were allowed to conduct the ICT in IBSE try-out with pupils (Figure 6.2c) whenever they were confident about their lesson plans; they did not have to wait until Sessions 5 and 6 for receiving feedback for improvement. They were even allowed to be absent in live session(s) if these sessions overlapped with their try-out plans.

In Session 7 scheduled for two half days in the second half of Week 5, participants took turns to report and evaluate their ICT in IBSE try-out, which was then commented on and formally evaluated by the course instructors (Figure 6.2d). The participants were encouraged to attend the entire session to comment on the classroom try-outs and learn from each other. The ICT in IBSE lesson plans plus the adapted/new Coach activities were shared among participants for future use. After the presentation and discussion about the ICT in IBSE try-out, the participants took the computer performance test.

### 6.3 Evaluation framework and instruments in the Vietnamese case study

In order to arrive at conclusions about validity of the pedagogical principles, usefulness of the support materials, and effectiveness of the ICT in IBSE course in the Vietnamese context, we addressed the following evaluation questions:

**A. About implementation of the pedagogical principles and the support materials in the Vietnamese context**

- **A1:** Was the “one theory-practice cycle” principle implemented faithfully?
- **A2:** Was the “distributed learning” principle implemented faithfully?
- **A3:** Was the “depth first” principle implemented faithfully?
- **A4:** Was the “ownership of learning” principle implemented faithfully?
- **A5:** Were the support materials useful for participants?

**B. About effectiveness of the Vietnamese ICT in IBSE course**

- **B1:** Did the course achieve its awareness objective?
- **B2:** Did the course achieve its ICT mastery objective?
- **B3:** Did the course achieve its ICT in IBSE objective?
- **B4:** Did the course achieve its motivation objective?

To address these questions, we adapted and used the evaluation framework and instruments, which were described in Chapter 3. We translated and used the following instruments for data collection and analysis in the Vietnamese case study:

- **Q1:** Pre-course questionnaire
- **Q2:** Post-course questionnaire
- **Q3:** Follow-up questionnaire
- **O1:** Observations of live sessions by the researcher
- **O2:** Observations of classroom try-outs by the researcher
- **O3:** Observations of live sessions by the course instructor
- **R1:** Report on practice with the ICT tool (Form 1)
- **R2:** Report on the ICT in IBSE lesson plan (Form 2)
- **R3:** Report on the ICT in IBSE try-out (Form 3)
- **I:** Inquiry-analysis Inventory
- **T:** Computer performance test
- **C:** Communication records
Table 6.2 shows which instruments were used and combined to collect and analyse data with respect to each evaluation question. The data-analysis outcomes regarding the above evaluation aspects are used to discuss the three research questions.

Considering the research conditions and the Vietnamese course scenario, we made a few adaptations of some instruments. In particular, we could not observe all ICT in IBSE try-outs directly (O2). It was because the try-out plans would overlap (the 22 try-outs within the 15 days), and many schools were very far from the course location (Hanoi). Therefore, the participants had to take initiatives to capture videos of their ICT in IBSE try-outs.

Table 6.2. Overview of instruments per evaluation question in the Vietnamese case study.

<table>
<thead>
<tr>
<th>Evaluation questions</th>
<th>Instruments*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1: Pre-course questionnaire</td>
<td>Q2: Post-course questionnaire</td>
</tr>
<tr>
<td>Q3: Follow-up questionnaire</td>
<td>O1: Observation of sessions (researcher)</td>
</tr>
<tr>
<td>Q2: Observation of classroom try-out</td>
<td>O2: Observation of classroom try-out</td>
</tr>
<tr>
<td>Q3: Observation of sessions (instructor)</td>
<td>O3: Observation of sessions (researcher)</td>
</tr>
<tr>
<td>R1: Report on practice with the ICT tool</td>
<td>R2: Report on the lesson plan</td>
</tr>
<tr>
<td>I: Inquiry-analysis Inventory</td>
<td>E: Inquiry-analysis Inventory</td>
</tr>
<tr>
<td>T: Computer performance test</td>
<td>C: Communication records</td>
</tr>
<tr>
<td>B1: Did the course achieve its awareness objective?</td>
<td></td>
</tr>
<tr>
<td>B2: Did the course achieve its ICT mastery objective?</td>
<td></td>
</tr>
<tr>
<td>B3: Did the course achieve its ICT in IBSE objective?</td>
<td></td>
</tr>
<tr>
<td>B4: Did the course achieve its motivation objective?</td>
<td></td>
</tr>
</tbody>
</table>

(*) The checkmark “✓” indicates which instruments were used for each question.

About the computer performance test (T), for the general design for the ICT in IBSE course, we developed three incomplete or problematic Coach activities corresponding to the three tools and used them to design three troubleshooting tasks (see Chapter 3, Section 3.3.5). For the Vietnamese course, we used these troubleshooting tasks to test the participants’ skills
to troubleshoot TCK problems. Moreover, we added *development tasks* that required the participants to develop a new Coach activity from scratch, using given information and regarding given criteria; for example, development of a new Coach video-measurement activity for pupils, using the video of a soap bubble moving back and forth next to the loudspeaker. This additional part of the computer test was to confirm if the participants reached the creator level of using the ICT tool. In short, the participants were tested on their knowledge and skills regarding their chosen ICT tool by a troubleshooting task and a development task of the computer performance test.

About the *communication records* as an instrument for data collection (C), we took initiatives to elicit and record participants’ formative feedback to get insight into the participants’ learning process and their possible difficulties. For the general design of the course, the communication with course participants took the form of a) interviews before and after live sessions and classroom try-outs, b) online consultation, and c) email coordination. For the Vietnamese course, the email coordination was not so important because of the many contact hours, and the online consultation was shifted to direct consultation in live meetings. Therefore, the *communication records* mainly took the form of observation, interview, and consultation notes of the researcher. To ensure reliability of the feedback from the participants, we encouraged them to feel free to share their opinions and difficulties while studying in live sessions and doing assignments on campus or in schools.

### 6.4 Implementation of the pedagogical principles and the support materials in the Vietnamese context

#### 6.4.1 About the “one theory-practice cycle” principle

Based on participants’ reports (R2, R3) and observations in live sessions (O1), we recorded that all 22 Vietnamese participants completed one theory-practice cycle. Most participants were able to finalise the Coach activity, the lesson plan, the classroom try-out, and the self-evaluation report at the intended moments during the course scenario (Table 6.3). Importantly, the fulfilment of this theory-practice cycle resulted in intensive reports about the ICT in IBSE try-outs in the formal assessment session (Session 7) as expected.

*Table 6.3. Number of Vietnamese participants who completed each stage of one theory-practice cycle.*

<table>
<thead>
<tr>
<th>Stages of the theory-practice cycle</th>
<th>Number of participants (N=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) completing the Coach activity</td>
<td>22</td>
</tr>
<tr>
<td>• between Sessions 4 and 5*</td>
<td>17</td>
</tr>
<tr>
<td>• between Sessions 5 and 6</td>
<td>5</td>
</tr>
<tr>
<td>b) completing the lesson plan</td>
<td>22</td>
</tr>
<tr>
<td>• between Sessions 5 and 6*</td>
<td>20</td>
</tr>
<tr>
<td>• between Sessions 6 and 7</td>
<td>2</td>
</tr>
<tr>
<td>c) completing the classroom try-out</td>
<td>22</td>
</tr>
<tr>
<td>• between Sessions 6 and 7*</td>
<td>22</td>
</tr>
<tr>
<td>• after Session 7</td>
<td>0</td>
</tr>
<tr>
<td>d) completing the self-evaluation report</td>
<td>22</td>
</tr>
<tr>
<td>• between Sessions 6 and 7*</td>
<td>21</td>
</tr>
<tr>
<td>• after Session 7</td>
<td>1</td>
</tr>
</tbody>
</table>

(*) The marks “*” indicate at which moment each stage was expected to be completed by all participants.
Almost all participants (21 out of 22) let pupils manipulate the ICT tool in their try-outs, and for 18 try-outs (82% of N=22), the lesson topic was within the current physics curriculum. About the context of the lesson, 16 try-outs (73% of N=22) were with a small group of 4 to 6 pupil volunteers, and 6 try-outs (27%) were regular lessons but with one-half of a class (Table 6.4).

Table 6.4. Number of the Vietnamese participants’ try-outs falling into each category by the lesson topic, the lesson context, and the manipulation of the ICT tool.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of try-outs (N=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In curriculum</td>
<td>18</td>
</tr>
<tr>
<td>Outside of curriculum</td>
<td>4</td>
</tr>
<tr>
<td>Context</td>
<td></td>
</tr>
<tr>
<td>Optional lesson with 4 to 6 pupil volunteers</td>
<td>16</td>
</tr>
<tr>
<td>Regular lesson with one-half of a class</td>
<td>6</td>
</tr>
<tr>
<td>Who manipulate the ICT tool?</td>
<td></td>
</tr>
<tr>
<td>Pupils</td>
<td>21</td>
</tr>
<tr>
<td>Teacher</td>
<td>1</td>
</tr>
</tbody>
</table>

Generally, the ICT in IBSE lesson plans were of acceptable quality. The participants recognised and appreciated technological and pedagogical issues of the actual implementation of ICT in IBSE activities. For more detail about evaluations on the participants’ intended and actual ICT in IBSE lessons, see Section 6.5.3.

6.4.2 About the distributed-learning principle

According to observations of live sessions by the researcher and the course instructor (O1, O3), the live activities were implemented as intended. The participants were satisfied with the format and timing for these live activities (responses via the post-course questionnaire, Q2). Via the assignment reports (R1, R3), the participants were asked to estimate how much time they spent for individual assignments, including time on campus, at home, and in schools. Based on the participants’ estimates, we calculated that they actually spent 16.4 hours (SD=4.1) for practicing the ICT tools, 12.3 hours (SD=7.7) for designing the ICT in IBSE lesson plans, and 9.1 hours (SD=2.8) for arranging and trying out the ICT in IBSE lessons with pupils. These data show that the participants invested more time outside live sessions than intended, 37.8 actual hours (SD=5.3) versus 30 anticipated hours.

The participants made use of a) most of the time intended for assignments on campus and b) direct, personalised, and timely help of the course instructors and peers. According to the communication records (C), the participants as non-users of Coach became acquainted with the platform and got over initial hurdles quickly. They studied the ICT tool gradually through practicing the Coach tutorial and exemplary activities and discussing difficulties with each other and with the course instructor. It took the participants the most time to troubleshoot TCK problems in adapting or developing the Coach activity for the ICT in IBSE lesson. A participant often consulted peers first (Figure 6.3a), and in case the help from the peers did not work out, then they together consulted the course instructor (Figure 6.3b). Via the post-course questionnaire (Q2), the participants evaluated the direct support from the course instructor and the fellow participants as very helpful (4.2 to 4.3 of the 5-point scale). These data show that scheduling individual assignments on campus was a relevant adaptation of the distributed-learning principle as it took advantage of the community of learners and the direct
consultation from the course instructor to compensate for the low entrance level of the ICT mastery of the participants.

Figure 6.3. Photographs of Vietnamese participants doing the individual assignments on campus and consulting each other (a) and the course instructor (b) when encountering serious problems.

Via the post-course questionnaire (Q2), we asked the participants whether they preferred the distributed scenario of the course as compared with a compact Coach workshop. Of 22 participants, 16 participants (73%) preferred the distributed scenario. These participants appreciated the distance part of the course where they could work at their own pace and try out their ICT in IBSE lesson plans with pupils. A particular feedback:

“The distributed scenario enabled me to learn the video-measurement tool to the level of the classroom application. So I could see pupils’ reactions and adjust my inquiry-based lesson with the tool for my future use. The classroom try-out took so much time to prepare and execute, so the course did not allow us to study all three ICT tools at the same level of depth. However, I myself became familiar with two other tools as well and knew their possibilities in physics education through reports of fellow participants. I think I can learn them by myself”.

According to the six others (27% of N=22), as far as all three ICT tools and non-IBSE use of these tools are concerned, application of ICT as physics experimentation/modelling tools in the current school conditions is more likely than the use of just a particular tool for pupil investigation in the physics class. Therefore, they liked the course as a compact workshop in which they could master basic manipulation skills with all three tools, and so they would find more possibilities across the current physics curriculum to apply these three tools with and without IBSE intentions after the course.

6.4.3 About the depth-first principle

According to the assignment reports (R1, R2, R3) and the communication records (C), all Vietnamese participants followed the one-tool specialisation to master skills to operate one ICT tool by choice, and then design, teach, and evaluate an ICT in IBSE lesson with pupils, using the chosen tool. One-half of the participants (11 out of 22) specialised in the video-measurement tool. They chose the video-measurement tool to study in depth because in their opinion, it is most applicable in Vietnamese schools among the three tools. The other half chose the data-logging tool (8 out of 11) or the modelling tool (3 out of 11) because these tools were newer for them.

Important, the participants were able to learn the chosen tool in depth. After the first week of the course, they could start to adapt or create a Coach activity for the ICT in IBSE
lesson plan. Of 22 participants, 12 participants (55%) modified the Coach exemplary materials for the ICT in IBSE try-out. The modifications involved not only revisions and translations of the embedded text instructions but also changes of the core experimentation/modelling activities. For example, by adding new model components, a participant transformed the given model describing a free fall (Figure 6.4a) to the model describing conservation of mechanical energy of a free-falling object and resulting in a good modelling graph (Figure 6.4b). The 10 others (45%) developed their Coach activities from scratch; these activities showed their sufficient skills with the ICT tool (Figure 6.5). While developing the Coach activity for the ICT in IBSE lesson, the participants encountered TCK problems and then troubleshoot these problems by themselves or in consultation with the course instructors and peers. The participants did write clear reports (R1) about their troubleshooting experience. According to observations of participants’ presentations about their Coach activities (O1, O3), almost all participants were able to manipulate the ICT tool fluently. Based on observations of classroom try-outs, 16 out of 22 participants (73%) were able to guide and support pupils effectively in implementing the Coach activities. For more detail about evaluations on the participants’ attainment of the ICT mastery, see Section 6.5.2.

![Figure 6.4. Screenshots of an original model describing a free fall (a) and a modified model describing conservation of mechanical energy of a free-falling object and modeling results (b).](image1)

![Figure 6.5. Screenshots of new Coach activities: a) investigation of the circular motion of a ceiling fan, using the video-measurement tool (pupils capturing and analysing the video with the teacher support) and b) investigation of damped oscillations in different situations (e.g. oscillation in water, a light oscillator with a big size), using a force sensor.](image2)
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The majority of the participants reported via the post-course questionnaire (Q2) that they were confident (i.e. moderately: 12 out of 22, very: 5 out of 22, extremely: 1 out of 22) to study by themselves the tools in which they did not specialise during the course (Table 6.5). Via the follow-up questionnaire (Q3), a half year after the course, eight participants reported that they actually continued studying and practising the ICT tools, which they did not learn in depth yet in the course.

Table 6.5. The Vietnamese participants’ confidence after the course in studying by themselves ICT tools in which they did not specialise during the course (5-point scale).

<table>
<thead>
<tr>
<th>Participants’ confidence level</th>
<th>Number of participants (N=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all confident</td>
<td>1</td>
</tr>
<tr>
<td>Slightly confident</td>
<td>3</td>
</tr>
<tr>
<td>Moderately confident</td>
<td>12</td>
</tr>
<tr>
<td>Very confident</td>
<td>5</td>
</tr>
<tr>
<td>Extremely confident</td>
<td>1</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>3.1 (0.9)</td>
</tr>
</tbody>
</table>

6.4.4 About the “ownership of learning” principle

According to observations of live activities (O1, O3, C), the participants looked focussed during the practice with the ICT tools. In small groups, they actively consulted each other and the course instructor about technological and pedagogical problems of their own ICT in IBSE lesson plans. However, they hesitated to comment on the lesson plans and try-outs reported by fellow participants in plenary and to convince the course instructors about their points of argument regarding their own ICT in IBSE lessons (Sessions 6 and 7). Only the course instructors provided feedback after each individual presentation as is common in Vietnamese higher education culture.

As most participants reported (C), they used much time to do home assignments not only on campus but also at home in the evening and at the weekends. Actually, they spent much more time for the ICT in IBSE course than for the parallel course. Especially for the participants who specialised in data logging with sensors, they asked for extra appointments on campus to speed up their learning of the tool and their preparation of the Coach activity for the ICT in IBSE lesson. Experimentation with data logging was dependent on the Coach hardware and laboratory equipment, which was limited, so could not be borrowed.

The participants submitted their assignments on time; the lesson plans (R2) and the self-evaluation reports on the classroom try-out (R3) were thoroughly written with sufficient details. However, they did not make full use of their freedom of choices for the ICT in IBSE lessons. Almost all ICT in IBSE try-outs (18 out of 22) were close to the curriculum. Topics of these try-outs involved well-known formulas, concepts, and constants, for example, measuring the gravitational acceleration \( g \) and measuring the formulas for the maximum distance travelled in projectile motion (horizontal launch), and oscillations involving springs. These concepts and formulas are explained and derived explicitly in the textbook.

The participants were proactive in preparing the ICT in IBSE try-out and managed to complete the try-out within the intended two weeks. Of 22 participants, 15 participants (68%) did borrow classes, get acquainted with pupils, and explore the pupils’ prior knowledge before the try-out. Almost all participants (21 out of 22) provided pre-lab
instruction about Coach. Although not required by the course, the participants decided to team up, and each team of two to four participants tried out their lesson plans in the same class. So together they provided the pre-lab instructions for the whole class (Figure 6.6a), and then each participant used a small group of the class for the try-out. All team members were present in the try-outs of each other to help capturing videos of the classroom activities (Figure 6.6b) and to provide feedback after the lesson. These observations and records (O2, C) show that empowering the participants was a good solution for insufficient school conditions for the ICT in IBSE try-out, and the community of learners turned out to be very helpful.

As far as the participants’ appreciation of the ICT in IBSE objective is concerned, we asked an open-ended question via the post-course questionnaire (R2). It was “considering the lack of equipment, pupils’ and teachers’ inexperience with ICT and IBSE, crowded curriculum, and big class size, someone said that it is not relevant yet to apply the inquiry teaching with ICT tools in regular teaching in Vietnamese schools. Do you agree with this statement? Please explain why.” Of 22 participants, 7 participants (32%) agreed with the statement. They argued that inquiry teaching with ICT is only relevant in an ideal context with small class size, active pupils, sufficient equipment, ample lesson time, and ample teacher preparation time. The other 15 participants (68%) did not agree with the statement. According to these participants, there are still ways of using ICT in IBSE methods that are suitable for current teaching situations in Vietnam. Importantly, Vietnamese teachers need to be aware of these patterns and able to adapt such patterns to their specific teaching circumstances. Two participants’ responses:

• “I partly disagree with this statement. Based on my experience of using the video-measurement tool, there is no lack of equipment. Schools have sufficient computers for video measurement activities, 2 or 3 pupils per computer. My pupils were interested in possibilities of investigating real life phenomena using video measurement, and they were diligent and able to study ICT skills fast to handle the tool. Consequently, I think that inquiry teaching with ICT is still likely, if teachers know when and how to apply this approach, for example, choosing topics, preparing pre-lab instruction, and designing suitable tasks.”

• “I do not think this statement is correct. We need to try out first to see what happens. For me, pupils with or without ICT/IBSE experience can be engaged in knowledge construction/verification, because there are many possibilities for exercising inquiry skills. Inquiry learning does not only take place during the execution of experiment but also before and after such..."
experiment. I myself now see many possibilities to apply the video measurement and modelling tools in the current curriculum. We need ICT facilities for ICT application, but simple use of ICT does not automatically enhance inquiry learning. In my opinion, the role of teachers is very important in enhancing inquiry learning of pupils, and ICT provides powerful tools for teachers to play this role.”

This feedback shows that the participants’ active participation in the ICT in IBSE course was not only because they were often obedient and diligent in doing coursework but also because they appreciated the relevance of the ICT in IBSE objective to pursue.

### 6.4.5 About the support materials

According to observations in contact hours (O1, C), the participants made use of the Coach introductory and tutorial activities as basics of studying the ICT tools. Direct personalised support from the course instructors and peers then came in and enabled them to get over initial hurdles and to troubleshoot problems, and so to gain ICT skills. Via the post-course questionnaire (Q2), the participants evaluated the Coach introductory and tutorial materials as very useful (4.2 to 4.4 of the 5-point scale) (Table 6.6). According to the participants (Q2, C), the exemplary Coach activities did not really fit the current physics curriculum, pupils’ background, availability of equipment in Vietnam, so they needed to modify or develop new Coach activities for their ICT in IBSE lessons. However, the exemplary Coach activities were still very useful for the participants (4.1 of the 5-point scale) as these activities showed additional features of the ICT tools and concrete examples of how to integrate these tools in IBSE lessons.

Table 6.6. The Vietnamese participants’ evaluation on the usefulness of each material to their learning during the course (5-point scale, 1 = not at all useful, 5 = extremely useful).

<table>
<thead>
<tr>
<th>Support materials</th>
<th>Usefulness of the material - Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory slides</td>
<td>3.4 (1.0)</td>
</tr>
<tr>
<td>Coach introductory activities</td>
<td>4.2 (1.1)</td>
</tr>
<tr>
<td>Coach tutorial activities</td>
<td>4.4 (1.0)</td>
</tr>
<tr>
<td>Coach exemplary activities</td>
<td>4.1 (1.1)</td>
</tr>
<tr>
<td>Form 2 for the lesson plan</td>
<td>3.7 (0.9)</td>
</tr>
<tr>
<td>Form 3 for evaluation of the try-out</td>
<td>3.6 (0.9)</td>
</tr>
</tbody>
</table>

Additionally, the following case reinforces the conclusion about the contribution of the Coach introductory, tutorial, exemplary materials to the attainment of the ICT-mastery objective:

Through the Vietnamese ICT in IBSE course, the local co-instructor found that the ICT tools were relevant, and it was possible for Master students to master these tools mostly on their own by using the Coach support materials. Consequently, he decided to introduce the ICT tools in another Master programme on physics education, which was at a different university very far from Hanoi (Tay Nguyen University). He brought the Coach equipment and software there and redesigned the ICT course, of which he was in charge. We were not involved in the redesign and implementation of this course at all. There were 14 Master students participating in the course, and like the Hanoi participants, they had to study the ICT tools by practicing the Coach introductory, tutorial, and exemplary materials, and then to adapt or create their own Coach activities for the ICT in IBSE lessons. The Coach activities produced by the participants showed their basic skills with the ICT tools and their suitable use of the tools for the current Vietnamese physics curriculum.
Forms for lesson plan and self-evaluation and the introductory slides were useful but received lower ratings (Table 6.6). Unlike the Coach activities, these materials were not self-contained and were used in interaction with the course instructor and so these had a different function.

### 6.5 Effectiveness of the Vietnamese ICT in IBSE course

In this section, we evaluate to what extent the Vietnamese ICT in IBSE course attained its four objectives. The data are presented and discussed per each course objective.

#### 6.5.1 Participants’ awareness of educational benefits of the ICT tools in science education

Via an open-ended question in the post-course questionnaire (Q2), each participant enumerated three to seven benefits of the ICT tools. The participants pointed out benefits of not only the tool they specialised in but also of the two others. Benefits of the ICT tools in improving conceptual understanding and bringing real life into the classroom were appreciated and mentioned by the majority of the participants (73% of N=22). Half of the participants remarked time efficiency of using the ICT tools to investigate sophisticated phenomena within the physics curriculum. About one third of the participants pointed out the benefit in stimulating pupils to exercise inquiry practices. Also one third of the participants enumerated that the use of these tools would acquaint pupils with dynamical modelling and ICT-enhanced measurement as “knowledge construction and verification” methods similar to those of scientists. Considering all responses together, the enumerated benefits matched with the ones that were discussed in the literature and/or reviewed in Chapter 2, Section 2.1.2.

In addition to benefits, the participants also enumerated cautions and suggestions for the use of the ICT tools in Vietnamese schools. In particular, the schools should be equipped with high-speed cameras and sufficient sensors to take the full benefits of the video-measurement and data-logging tools and make pupils’ investigations with these tools more likely. Modelling is relevant in physics education, but it is difficult for Vietnamese pupils to understand the modelling process and to handle the modelling tool independently. Teacher-led demonstrations for the whole class and thoroughly guided practice for a small pupil group are pragmatic solutions, which enable the teacher to deal with insufficient material conditions and pupils’ ICT inexperience while still taking advantages of the ICT tools to some extent. The participants’ enumerations show their sufficient awareness of educational benefits and cautions of using the ICT tools in their classrooms.

#### 6.5.2 Participants’ skills to operate the ICT tools

Via the post-course questionnaire (Q2), the participants were asked about their confidence level concerning particular manipulations of each of the three ICT tools. According to participants’ ratings, the participants who specialised in the data-logging and video-measurement tools were very confident in operating their chosen ICT tool (4.0 to 4.8 of the 5-point scale, Table 6.7). The participants who specialised in the modelling tool felt very confident in using and revising a given model (4.3 of the 5-point scale), but less confident in developing a new model (3.3 of the 5-point scale). Table 6.7 shows that the participants were not so confident in manipulating the tools (1.8 to 3.4 of the 5-point scale), which they did not
study in depth during the course. This result was obvious, and it indicated that the participants did not provide their ratings randomly.

Table 6.7. Confidence levels of the Vietnamese participants for particular manipulations of the tool in which they specialised and of the two others (5-point scale, 1=not confident at all, 5=extremely confident).

<table>
<thead>
<tr>
<th></th>
<th>Confidence level of participants</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>who specialised in the tool</td>
<td>who did not specialise in the tool</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N = 8</td>
<td>N = 14</td>
<td></td>
</tr>
<tr>
<td><strong>1. Data logging</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1. Connecting sensors and an interface to a computer</td>
<td>4.8 (0.4)</td>
<td>2.2 (0.9)</td>
<td></td>
</tr>
<tr>
<td>1.2. Setting sensor connection in the software</td>
<td>4.8 (0.4)</td>
<td>2.0 (0.7)</td>
<td></td>
</tr>
<tr>
<td>1.3. Setting time-based measurement</td>
<td>4.8 (0.4)</td>
<td>2.1 (1.2)</td>
<td></td>
</tr>
<tr>
<td>1.4. Setting event-based measurement</td>
<td>4.3 (0.8)</td>
<td>1.9 (0.9)</td>
<td></td>
</tr>
<tr>
<td>1.5. Setting a measurement based on a trigger event</td>
<td>4.5 (0.5)</td>
<td>2.1 (1.2)</td>
<td></td>
</tr>
<tr>
<td>1.6. Determining the calibration factors of a sensor</td>
<td>4.0 (0.9)</td>
<td>1.9 (0.8)</td>
<td></td>
</tr>
<tr>
<td><strong>2. Video measurement</strong></td>
<td>N = 11</td>
<td>N = 11</td>
<td></td>
</tr>
<tr>
<td>2.1. Making scale settings</td>
<td>4.6 (0.6)</td>
<td>3.1 (0.9)</td>
<td></td>
</tr>
<tr>
<td>2.2. Specifying features of the coordinate system</td>
<td>4.6 (0.6)</td>
<td>3.4 (1.0)</td>
<td></td>
</tr>
<tr>
<td>2.3. Setting time calibration for video</td>
<td>4.6 (0.6)</td>
<td>2.8 (1.1)</td>
<td></td>
</tr>
<tr>
<td>2.4. Performing perspective correction</td>
<td>4.4 (0.9)</td>
<td>2.5 (0.9)</td>
<td></td>
</tr>
<tr>
<td>2.5. Correcting video points by dragging wrong measured points to the correct position</td>
<td>4.2 (1.0)</td>
<td>2.6 (0.8)</td>
<td></td>
</tr>
<tr>
<td>2.6. Setting point tracking by which measurement is performed automatically</td>
<td>4.6 (0.6)</td>
<td>3.2 (1.1)</td>
<td></td>
</tr>
<tr>
<td><strong>3. Modelling</strong></td>
<td>N = 3</td>
<td>N = 19</td>
<td></td>
</tr>
<tr>
<td>3.1. Using a given model to understand a phenomenon</td>
<td>4.3 (0.5)</td>
<td>2.6 (1.1)</td>
<td></td>
</tr>
<tr>
<td>3.2. Exploring to gain insight into a given model</td>
<td>4.3 (0.5)</td>
<td>2.6 (1.0)</td>
<td></td>
</tr>
<tr>
<td>3.3. Making a small change to a given model</td>
<td>4.3 (0.5)</td>
<td>2.3 (1.0)</td>
<td></td>
</tr>
<tr>
<td>3.4. Developing a graphical model</td>
<td>3.3 (0.5)</td>
<td>1.8 (0.8)</td>
<td></td>
</tr>
</tbody>
</table>

Regarding the Coach activities, 10 out of 22 participants (45%) created their own, new Coach activities (Figure 6.5), whereas 12 others (55%) modified the Coach exemplary materials. Of 22 participants, 21 participants prepared text instructions for the Coach activity in advance and let pupils manipulate the ICT tool in the ICT in IBSE lesson. Of these 21 participants, 15 participants (71%) wrote the text instructions instructively and clearly, so pupil groups with no experience with the ICT tools could follow and execute the Coach activity with a little help of the teacher. Meanwhile, the six other participants (29% of N=21) wrote unclear and insufficient text instructions, so pupils encountered problems in understanding tasks and executing experiments and got inappropriate experiment data from the beginning. In their try-outs, these participants were unintendedly too busy reacting to
questions of different pupil groups. Eventually, just one or two groups got some acceptable data, and there was no time left for discussions.

Regarding the computer performance test, each participant took a test package (incl. a troubleshooting task and a development task) regarding her or his chosen ICT tool. Almost all participants (19 out of 22) troubleshooted the test problem successfully (Table 6.8) and were able to demonstrate their fluent manipulations during the test. Of 8 participants who took the data-logging test package, 5 participants (63%) could develop new data-logging activities using given sensors, and their new activities resulted in acceptable data to be discussed. Of three others, two participants got inaccurate data from their activities, and one participant could not make her experimental setup work. About the video-measurement package, 11 participants had to create a worthwhile video-measurement activity, using the video of a soap bubble moving back and forth next to a loudspeaker. Six participants (55% of N=11) completed this task. Five others could also get data and graphs from the video, but their video-measurement activities trivially involved the motion of only the loudspeaker surface or only the bubble, and so the measured graphs did not connect to any physics concepts. Of three participants who took the modelling test package, two participant (66%) could finalise a new model about the motion of a satellite around the earth, using the given information and formulas. Of 22 participants, 11 participants (50%) did complete both a troubleshooting task and a development task. These data show that the majority of the participants were confident in troubleshooting TCK problems and developing a new Coach activity from scratch, and a half of the participants achieved troubleshooting skills to certain extent.

Table 6.8. Number of Vietnamese participants who completed the troubleshooting task and the development task within the test package regarding to the ICT tool in which they specialised.

<table>
<thead>
<tr>
<th>Test package</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data-logging test package</td>
<td>N = 8</td>
</tr>
<tr>
<td>• Completed the troubleshooting task</td>
<td>7</td>
</tr>
<tr>
<td>• Completed the development task</td>
<td>5</td>
</tr>
<tr>
<td>Video-measurement test package</td>
<td>N = 11</td>
</tr>
<tr>
<td>• Completed the troubleshooting task</td>
<td>10</td>
</tr>
<tr>
<td>• Completed the development task</td>
<td>6</td>
</tr>
<tr>
<td>Modelling test package</td>
<td>N = 3</td>
</tr>
<tr>
<td>• Completed the troubleshooting task</td>
<td>2</td>
</tr>
<tr>
<td>• Completed the development task</td>
<td>2</td>
</tr>
</tbody>
</table>

### 6.5.3 Participants’ ability to design, implement, and evaluate an ICT in IBSE lesson

**a) Ability to design**

We used the inquiry-analysis inventory (I) to analyse all 22 ICT in IBSE lessons and to code which inquiry skills were a) aimed at as inquiry objectives, b) operationalised in the lesson plans (R2) as learning opportunities for pupils, c) exercised by the majority of pupils in the classroom try-outs (R3, O2). The result was that 5 inquiry skills on average (SD=2) were operationalised per lesson plan, whereas the participants aimed at achievement of 9 inquiry skills on average (SD=2) per lesson. Almost all participants (19 out of 22) operationalised just part of the intended inquiry objectives in their ICT in IBSE lesson plans. Actually, it was not so much the number that counted but the inclusion of skills from the three phases: planning,
execution, and interpretation. Figure 6.8 shows the following inquiry skills, which were operationalised most frequently in the 22 lesson plans:

- **Component 1.3a**: defining variables of experiment/model (16 out of 22)
- **Component 2.1**: manipulating software/apparatus to construct and/or execute the experiment/model (21 out of 22)
- **Component 2.2**: observing and/or measuring experimental variables or determining resulting values of modelling variables (19 out of 22)
- **Component 3.3**: determining qualitative and/or quantitative relationships (17 out of 22)

Among these four components, components 1.3a and 3.3 were emphasised as we expected. The following case illustrates how a participant focussed on several inquiry components and operationalised realistic but relevant inquiry opportunities for pupils:

A participant designed prescriptive instructions for an experiment using a smart pulley (incl. a photo gate and attached pulley with spokes) to verify the value of the acceleration due to gravity (g). At the beginning of the lesson, he left out part of the experiment design for pupils to figure out for themselves. The following pattern of questions was used to stimulate pupils: *which variables do you measure? What tools do you need? How to arrange them? What procedures do you follow? How will you analyse results?* After the discussion on the design, the pupils were introduced to the equipment and sensors and given the written instructions to execute the experiment on their own. Figure 6.7 shows that his pupils could actually propose a conceptual design of an experiment (by sketching) (**component 1.3a**, Figure 6.7a), which was close to the real experimental set-up (Figure 6.7b). Additionally, the pupils could propose how to get g from a graph of how many spokes of the pulley had passed the photo gate versus time (**component 1.3c**, Figure 6.7c). So they did execute the experiment (**component 2.1**) partly according to their own design (**component 2.5**), while using the manipulation instructions prepared by the teacher beforehand. By this way, the pupils with little ICT experience did collect sufficient data for follow-up group discussions on data analysis and interpretation (**component 3.3**).

This is a nice example of first taking cookbook instructions for an experiment and then creating gaps in these instructions where pupils have to think for themselves what to measure and how to measure it. This is a limited way of doing IBSE, but it was well thought out and well implemented.

![Photographs of pupils’ activities within an ICT in IBSE try-out: designing an experiment (a) and executing the experiment according to the own design (b) and a screenshot of their data graph (c).](image-url)
Chapter 6

The list of 22 categories of inquiry skills within the ICT in IBSE activity:

1. **Conception, planning and design**
   - the pupil
     1.1 formulates a question
     1.2 formulates an hypothesis or expectation
     1.3a defines variables of experiment/model
     1.3b defines how each variable will be measured or modelled
     1.3c defines procedures to analyse experimentation/modelling data
     1.4 predicts results of experiment/model based on its design

2. **Execution of experiment/model**
   - the pupil
     2.1 manipulates software and/or apparatus
     2.2 measures/determines values of variables
     2.3 records experimentation/modelling data
     2.4 decides/explains experimentation/modelling techniques
     2.5 works according to the own design

3. **Analysis and interpretation**
   - the pupil
     3.1 chooses representations of data
     3.2 determines accuracy and precision of data
     3.3 determines relationships
     3.4 compares the results to the hypothesis/prediction
     3.5 explains experiment/modelling results
     3.6 discusses limitations of the experiment/model
     3.7 proposes generalizations of the results

4. **Applications and follow-up**
   - the pupil
     4.1 predicts on basis of obtained results
     4.2 formulates new questions
     4.3 formulates hypotheses for follow-up
     4.4 applies the techniques to a new problem

**Figure 6.8.** Number of Vietnamese lesson plans (out of total 22) in which each inquiry component (1.1 to 4.4) was operationalised as a learning opportunity (and not a prescriptive recipe) for pupils. Each participant designed one ICT in IBSE lesson plan.

Almost all participants focussed on pupils executing the experiment or model (components 2.1 and 2.2) in their lesson plans, but very few or no participants intended for their pupils to formulate a hypothesis (component 1.2), predict results of experiment/model (component 1.4), and explain experiment/modelling results (component 3.5). Meanwhile, these components could enable pupils to think back and forth between the physical and theoretical worlds and stimulate their conceptual understanding. Moreover, of 16 participants who planned to engage pupils in partly designing the experiment/model, only 3 participants (19%) prepared for their pupils to **work according to the own design** (Figure 6.8). These analysis outcomes matched with the classification of the lesson plans according to the inquiry continuum (see Chapter 2, Section 2.2.3): most of the lesson plans (15 out of 22) fell into the pattern of **guided discovery** (Figure 6.9). Under this pattern, the teacher would thoroughly guide pupils’ experimentation/modelling activities through **plenary systematic explanations** and **prescriptive worksheets** for the group work with respect to discovery/verification of
knowledge, which was given in the textbook and/or by the teacher beforehand. In the minority of the lesson plans (27% of N=22), pupils would be given more freedom and independence to inquire unknown knowledge with or without procedures given by the teacher (guided inquiry or bounded inquiry) (Figure 6.9). None of the participants intended open inquiry for their ICT in IBSE lessons, where pupils were expected to propose and pursue their own research questions and experimental design.

Figure 6.9. Number of Vietnamese ICT in IBSE lesson plans categorised in certain patterns of inquiry teaching.

b) Ability to implement

Of 116 inquiry opportunities operationalised in the 22 lesson plans, 78 opportunities (67%) were realised in the ICT in IBSE try-outs as the majority of pupils took such opportunities to exercise inquiry skills. Especially, the two bounded-inquiry lessons with more participation and independence of pupils were implemented faithfully as illustrated in the following vignette:

Via an extracurricular activity in a countryside school, a participant first provided her three grade-7 pupils (13-14 years old) with pre-lab training on Coach video measurement in a half day, using the Coach tutorial activities. Next, she assigned the pupils to determine if traffic vehicles while crossing their school gate exceeded the speed limit regulated by the local government. After that, these pupils by themselves designed the scenario and setup for appropriate video recording (Figure 6.10a); calibrated time and scale of the video; collected video data; processed and interpreted the velocity versus time graph; and wrote a report to the teacher. The pupils’ report and Coach activity showed their basic ICT skills and their understanding of kinematics concepts and graphs. According to the participant, these pupils planned to investigate different motions that they often saw on the way to school, using the Coach software. So, through this bounded inquiry activity, the pupils actually exercised the following inquiry skills: 1.3a, 1.3b, 1.3c, 2.1, 2.2, 2.3, 2.5, 3.1, 3.3, and 4.4.

This case exemplifies that an ICT in IBSE activity with much independence and participation of pupils can be effective in the Vietnamese context. Vietnamese pupils are easily motivated when seeing how science concepts function in real-life contexts, which they rarely see in their regular physics classes. If prepared sufficiently, they are able to handle an open task.
Deviations from the intended inquiry opportunities in the actual inquiry activities occurred in most ICT in IBSE try-outs (17 out of 22). According to the classroom observations (O2) and the participants’ self-evaluation reports (R3), these deviations resulted from the following problems:

First, in more than a half of the try-outs (12 out of 22), the participants systematically derived formulas from prior theory before the verification experiment, following steps in the textbook and interacting with pupils during the derivation process (Figure 6.11a). Five try-outs were preceded by extensive theoretical derivations (three fourths of the lesson time). Consequently, the remaining time was just enough for pupils to collect some experimentation/modeling data; these pupils did not have opportunities to analyse and interpret the data as expected.

Second, in almost all ICT in IBSE try-outs (21 out of 22), pupils were assigned to work in groups to conduct experiments/models. In seven try-outs, the participants organised and coordinated their pupils’ group work ineffectively. Each group included 4 to 5 pupils per laptop, and often then, two or three pupils were partly left out (Figure 6.11b). In mixed groups, male pupils handled the laptop, whereas female ones merely watched. The pupils discussed very little with each other in groups. The teachers did not act on these problems at all. In these try-outs, just a few pupils were actually engaged in exercising inquiry skills in the execution phase.

Third, three participants assigned their pupils to make video measurement activities from scratch, using prescriptive text instructions, which were too long, but insufficient. Due to this, pupils’ manipulations with the software dominated the entire ICT in IBSE lesson. The
teachers were unintendedly too busy with answering and assisting the technical questions of different pupil groups. These lessons ended while almost all groups kept struggling with incomplete Coach activities and/or inappropriate resulting data. In these try-outs, conceptual goals and inquiry intentions drowned in many but unnecessary manipulation problems.

Fourth, five participants reported that they could not interact with pupils effectively in the planning phase. In particular, two participants took too much time reacting to different designs of the experiment proposed by pupils and convincing the pupils about irrelevance of their designs. The three other participants self-evaluated that their questions were unclear and unexciting, so did not engage their pupils in discussing the experiment design as expected. After that, they provided some hints, but these also did not work in eliciting pupils’ ideas.

Additionally, there was a specific problem related to five fresh-graduate participants, who had little teaching experience. There were more deviations in their try-outs than in the try-outs of other participants, who had experience with teaching and classroom management. Some experienced-teacher participants were good at systematic explanations with little details and skilled in dealing with pupils, for example, leaving time and space for pupils’ independent work and listening to the pupils carefully (Figure 6.12a). Meanwhile, the five fresh-graduate participants in the classroom looked a bit stressed; talked much but sometimes unclearly; and kept interfering with pupil groups while the pupils were reading the written instructions and executing the experiment (Figure 6.12b). Accordingly, they unintentionally shortcut their intended inquiry opportunities, for example, providing information instead of letting pupils think and answer or assigning pupils to sketch a conceptual design of an experiment, whereas the actual setup of the experiment was already in front.

![Figure 6.12. Photographs of an experienced-teacher participant (a) and a fresh-graduate participant (b) in their ICT in IBSE try-outs.](image)

### c) Ability to evaluate

Of 22 participants, 15 participants (68%) described the achievement of their inquiry objectives clearly in their self-evaluation reports (R3) and presented it in Session 7 (i.e. formal assessment session) with convincing evidence from pupils’ Coach result files and worksheets and classroom photographs and videos. Almost all illustrative images about the try-outs in this chapter were selected from the participants’ self-evaluation presentation slides. Of the 7 other participants, 4 participants stated the goal achievement without evidence, and 3 participants claimed realisation of some inquiry opportunities that contradicted our research data. About implementation of the ICT in IBSE lesson, the participants did indicate and explain relevant self-evaluation points about what did not go as intended in their try-outs.
Considering our classroom observations (O2) and analysis of pupils’ Coach result files and worksheets, there were, however, different deviations to those indicated by the participants. These different points were raised and discussed in the formal assessment session (Session 7), and then agreed by the participants.

Regarding the future use of the ICT in IBSE lesson plan, nine participants would keep the lesson plan unchanged for different classes, if the number of pupils, the timeframe, and pupils’ experience with the ICT tool would be similar to those of the try-out. Of the 13 other participants, four participants planned to skip theoretical derivations in the first half of the lesson and start with the formula right away with brief explanations and references to the textbook. They wanted to focus on pupils’ discussions about the design of the verification experiment. Six participants would lower complexity of the Coach activity by reducing the number of tasks and limiting manipulations required for data collection. They would place more emphasis on pupils’ data processing and interpretation and conceptual discussion afterwards. Additionally, five participants would like to provide pupils with more freedom to use the ICT tools to solve problems raised by the teacher as illustrated in the following report:

“In the try-out, my pupils handled Coach much better than I expected. Via a manual worksheet, I instructed them to collect video data manually, but in fact most pupils used the point-tracking function, which had been introduced to them in a half-day pre-lab session. Some pupils even manipulated the software more fluently than I could. This made me think that perhaps I should make the worksheet less prescriptive; give only part of the prepared worksheet and only when pupils ask for; or even not give it to them at all. To realise this, I will arrange one more training session for pupils to really grasp basic skills with video measurement. I also need to define suitable problems for pupils to investigate with Coach and prepare a backup plan in case they cannot design and implement a video measurement activity on their own as expected.”

In the formal assessment session (Session 7), the course instructors generally agreed with the suggested revisions for implementation in different classes and provided the participants with additional ways to improve the lesson plan. The above data lead us to the conclusion that the majority of the participants were capable of self-evaluating the implementation of inquiry opportunities with the ICT tool in their try-outs.

6.5.4 Participants’ motivation to study the ICT tools further and to try out more ICT in IBSE lessons

Via the post-course questionnaire (Q2), 15 out of 22 participants (68%) reported their plans to continue studying ICT tools after the course. They would use the given support materials for their self-study, and in case of encountering problems with a particular tool, they would consult fellow participants who specialised in that tool during the course. Eight participants (36% of N=22) devised plans to review the ICT in IBSE lesson plans of fellow participants and adapt them for implementation in their own classes. Seven participants (32% of N=22) were motivated to design new ICT in IBSE lessons and participate in coming teaching competitions in their schools with such lessons. Five participants (23% of N=22) planned to use the ICT tools for their Master research project (see below), and four participants (18% of N=22) would guide their pupils using the ICT tools in science fair among teams of secondary school pupils. Of 22 participants, five participants (23%) did not have any plans to study or use the ICT tools right after the course. This feedback shows that
the majority of the participants were *motivated to continue studying and applying* the ICT tools after the course.

The follow-up questionnaire (Q3) was administered to all 22 participants of the course half a year after the course, and then 20 participants (91%) reacted. Two participants declined our invitation for the questionnaire, because they were not teaching at that time. Of 20 respondents, 12 participants (60%) actually continued studying the ICT tools on their own. In particular, 7 participants (35% of N=20) further developed their knowledge about the tool which they tried out with pupils during the course. Especially, 8 participants (40% of N=20) were able to study the tools in which they did not specialise during the course. About incorporation of ICT and IBSE in the classroom, 9 participants (45% of N=20) taught more ICT in IBSE lessons; 4 participants (20% of N=20) taught lessons with the ICT tools but not in inquiry ways; and 12 participants (60% of N=20) taught more IBSE lessons but not using the ICT tools. However, 7 participants (35% of N=20) did not teach either ICT or IBSE lessons since completing the course. Apart from continuous applications of the ICT tools in regular teaching, there were specific applications of the tools by a few participants:

A participant guided his pupils’ research projects using the ICT tools, which won the third prize in a provincial-level science fair for pupils\(^1\). Two other participants used the video-measurement tool for their Master research projects. In particular, one participant developed and tried out a lesson series with Coach video-measurement activities, which was aimed at grade-10 pupils acquiring inquiry skills and learning kinematics. The other participant let grade-12 pupils in extracurricular activities investigate motion characteristics of different pendulums, which were close to real life but not mentioned in the secondary school physics textbook (e.g. tumbler-like pendulum, oscillator with a leaf spring, and torsion pendulum). He published his successful experience of guiding pupils’ extracurricular video-measurement projects in an article in a Vietnamese journal for teachers (T.T. Tran, 2015).

So half a year after the course, the majority of the participants had studied the ICT tools further and had taught more ICT and/or IBSE lessons as they planned right after the course.

Half a year after the course, the participants’ motivation and confidence regarding ICT/IBSE teaching remained positive in realistic school conditions. In particular, most participants remained confident to study the ICT tools further by themselves (80% of N=20) and held the opinion that their pupils should get experience with ICT tools (85% of N=20) and inquiry-based learning (90% of N=20). Of 20 respondents, 11 participants (55%) asserted that they found ICT and IBSE teaching worthwhile in spite of insufficient school conditions, and they were able to find opportunities for ICT/IBSE incorporation in spite of the constraints. According to these participants, their motivation was reinforced by effective engagements of pupils in their ICT/IBSE lessons and school boards’ encouragement with respect to innovation demands.

Via the follow-up questionnaire, the participants were asked to look back and evaluate the effects of the ICT in IBSE course. Almost all respondents (19 out of 20) appreciated the effects of the ICT in IBSE course and evaluated that the course was relevant to be included in the Master programme on physics education. Of 20 respondents, 14 participants wished to have a longer course so that they could study all three ICT tools, and with the help of peers.

\(^1\) It was a local version of the Intel International Science and Engineering Fair: https://www.societyforscience.org/intel-international-science-and-engineering-fair

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and the course instructor, they could develop more Coach activities, which are meaningful and suitable for the local physics curriculum. The 6 other participants suggested to keep the same contact hours but stretch the course longer so that they could have more time to appreciate possibilities of the ICT tools, to choose appropriate ICT in IBSE topics, and to prepare for the try-out in schools. Additionally, almost all respondents (18 out of 20) desired follow-up courses in order to discuss their recent ICT/IBSE teaching experience and to continue trying out ICT in IBSE lessons, but with a whole class, and then to get feedback from the course instructor and peers. A particular response:

“Through the course, I got to know Coach and introduced it to pupils. The integration of Coach made my physics class more exciting and more close to everyday context. Moreover, I became aware of what IBSE involves in the classroom and gained exposure to implementing an IBSE lesson with pupils, but I did not yet become skilled at implementation of IBSE, especially with 35 to 45 pupils. Therefore, I want an extra course on these topics with the fellow Master students. With this follow-up course, we will focus on implementation of ICT in IBSE lessons with a whole class and consider all realistic school conditions. This course will be practically relevant for us to prepare for more frequent ICT/IBSE teaching required by the curriculum reform”.

This feedback shows positive effects of the course on the Master students and their motivations for actual ICT and IBSE incorporation in the classroom.

### 6.6 Final conclusions and discussion of the chapter

In the Vietnamese case study, we first explored the Vietnamese context, and based on this exploration, we clarified the expected attainment levels of the four course objectives. After that, we operationalised the four pedagogical principles in the Vietnamese course scenario, using the support materials with respect to these expected attainment levels of the four objectives. In the following sections, we conclude and discuss the attainment of the four objectives of the Vietnamese ICT in IBSE course, the validity of the four pedagogical principles, and the transferability of the ICT in IBSE course in the Vietnamese context as well as the challenges and potential solutions to the application of IBSE in the Vietnamese hierarchical education culture.

#### 6.6.1 Conclusions and discussion about effectiveness of the Vietnamese ICT in IBSE course

**a) About the awareness objective**

The awareness objective: *participants become aware of educational benefits of the ICT tools.*

Expected attainment level: after the course, the Vietnamese participants could enumerate one or two relevant benefits of each of the three ICT tools.

The data presented in Section 6.5.1 show that the participants enumerated one or two relevant benefits of not only the tool in which they specialised but also each of the other two tools. At the individual level, several benefits were not mentioned. However, considering the entire group, the participants did point out almost all benefits of the three ICT tools as discussed in Chapter 2, Section 2.1.2. Furthermore, they became aware of cautions of using
these ICT tools in their classrooms. To conclude, the awareness objective of the Vietnamese ICT in IBSE course was better achieved than expected.

b) About the ICT mastery objective

The ICT mastery objective: participants master skills to operate the ICT tool.

Expected attainment level: after the course, the Vietnamese participants should reach the adaptor-user level or the creator-user level for their specialised tool.

Sections 6.4.3 and 6.5.2 presented the participants’ ICT mastery considering the data from the computer performance test; from the Coach activities; from the observations of live presentations and classroom try-outs with the ICT tools; and from the post-course questionnaire. These data were in line with each other and confirmed that the participants were confident (Table 6.5) and able to operate the tool in which they specialised. The participants were capable of modifying (12 out of 22) or creating (10 out of 22) the suitable Coach activities for their ICT in IBSE lessons. Furthermore, a half of the participants were successful in both individually troubleshooting a TCK test problem and developing a new Coach activity from scratch by themselves, according to the test requirements. Therefore, we conclude that the participants achieved the ICT mastery from adaptor-user level to the creator-user level and the expert level. This achievement of the ICT mastery objective of the Vietnamese ICT in IBSE course was beyond our expectation before its implementation. It resulted from the fact that the participants spent many contact hours (incl. about 5 hours in live sessions and 20 hours for individual assignments on campus) to practice the ICT tool by choice with the Coach support materials and to troubleshoot the TCK problems with direct and personalised support from the course instructor and peers.

c) About the ICT in IBSE objective

The ICT in IBSE objective: participants can design, implement, and evaluate an ICT in IBSE lesson.

Expected attainment level: concerning the ability to design, the Vietnamese participants were expected to be able to operationalise most of their inquiry objectives as inquiry opportunities in the lesson plan. In about half of the lesson plans, one or two inquiry skills from categories 1.1 to 1.4 and 3.3 to 3.7 would be operationalised. Concerning the ability to implement, we expected about half of the inquiry opportunities (specified in lesson plans) to be realised in the classroom. Additionally, we expected that about half of the participants would be able to self-evaluate their classroom try-outs.

The data presented in Section 6.5.3 show that the participants did operationalise about half of the intended inquiry skills as learning objectives in their lesson plans as inquiry opportunities (5 out of 9 per lesson, on average). Among the categories which involved minds-on inquiry (1.1 to 1.4 and 3.3 to 3.7), the categories 1.3a (defining variables of experiment/model) and 3.3 (inferring relationships) were operationalised in most lesson plans (16 and 17 of 22) as expected. However, very few or no participants intended for other minds-on categories. Instead, most of the participants focussed on pupils executing the experiment or model (hands-on categories 2.1 and 2.2), but intended to take control of the entire activity through systematic plenary explanations and prescriptive worksheets. In their ICT in IBSE
try-outs, the participants were able to realise most of the intended inquiry opportunities (78 out of 116), although they encountered serious implementation problems such as too long derivations before IBSE, poor group management, dominant of ICT manipulations over minds-on inquiry exercises, and ineffective communication with pupils. After the try-outs, the majority of the participants were capable of evaluating achievement of their inquiry objectives; indicating and explaining deviations from the intended inquiry opportunities in the actual inquiry activities; and suggesting relevant changes of their lesson plan for future implementation. To conclude, the Vietnamese ICT in IBSE course achieved its ICT in IBSE objective as predicted, but also with much room and many suggestions for improvement.

The course focussed on teacher learning to teach by inquiry with ICT, and the participants got their first classroom experience with such innovative teaching, but did not get far yet. We recorded a nice first step towards IBSE within the constraints of curriculum and the teacher experience: a few participants generated ingenious ways to get their pupils involved in designing experiments in a typical verification laboratory in Vietnamese schools. However, the majority of the participants encountered persistent problems of translating their theoretical knowledge of IBSE into concrete lesson designs and of implementing IBSE intentions in the classroom environment. Indeed, the course had to take more than its 60 study hours for the participants to truly appreciated integration of the ICT tools into inquiry-based teaching. This matches with many studies of IBSE implementation including the review of Supovitz and Turner (2000), who reviewed large systemic change processes towards inquiry learning in the U.S. and concluded that a minimum of 100 contact hours (including coaching) was needed to get any visible change in the classroom.

The participants received feedback on the lesson plan for improvement from the course instructors (but not from fellow participants) through the extensive, plenary presentation sessions (Sessions 5 and 6). However, the participants still encountered implementation problems, which partly resulted from a) insufficient school conditions (that we cannot change), b) complex nature of ICT in IBSE teaching, and c) inexperience of teachers with inquiry teaching with and without ICT. Regarding the two latter factors, the participants should have been supported more effectively with more personalised and practical advice. In particular, for future optimisation of the course, we would replace the extensive presentations (Sessions 5 and 6) with personalised consultation and small group work in analysing and criticising the ICT in IBSE lesson plans. Two or three participants and the course instructor should sit down, go through each lesson plan, and make corrections right away. In this way, an individual participant would get more use of physics-education expertise of the course instructor and of rich teaching experience of fellow participants. For example, group work of four to five pupils can still be effective if each pupil has a particular role (e.g. chairing, manipulating equipment, recording data, analysing data, and reporting), and half way, pupils’ physical locations and roles are switched. The participants should be cautioned to keep the focus on the main inquiry learning objectives and not distract pupils with irrelevant or impossible tasks like assigning pupils with little ICT skills to create a video-measurement activity from scratch in limited lesson time. This way, problems like ineffective group work of pupils, too long theoretical derivations, and overloaded ICT-manipulation tasks could be reduced. Furthermore, the participants would learn to analyse their lesson plans more critically.
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The research findings led us to ponder two questions. First, why did most Vietnamese participants choose a topic and context limited to the curriculum and mainly verification activities, whereas their try-outs were outside regular lessons (Table 6.4), and they were capable of handling the ICT tools in broader contexts (e.g. stimulating and supporting pupil investigation of knowledge outside of the curriculum in a real-life situation)? Second, why did most teachers take control over the entire classroom activity, whereas with small class size and sufficient ICT facilities (because of the limited number of pupils) as they had in the try-outs, they could have provided more open inquiry activities for pupils? In our opinion, the following reasons were involved. First, the participants were relying much on the textbooks, teacher books, and support materials (given in the course and previous Master courses) and considered these as standardised materials for good teaching, whereas these materials were not sufficiently open to serve as examples of IBSE. Second, the participants were used to preparing everything for pupils, so they did not see what pupils could do in a more open situation. The participants were hesitating to give much freedom to pupils, and then perhaps encounter unexpected problems that they could not handle, so a guided lesson would be safer. In spite of studying IBSE theory, their perception of IBSE was very different from the common perception of science educators. The main reasons are probably that the participants never experienced open investigations themselves and that they are embedded in a hierarchical education system in which teachers and pupils are supposed to follow directions.

The ICT in IBSE course was meant for teachers to be pushed further than where they used to go. The participants should go out of their comfort zone by trying out more-open ideas with the ICT tools, trusting and giving their pupils enough freedom, and aiming at learning of concepts and phenomena that are not on the next page of the textbook. In fact, two Vietnamese participants within the course (ICT in IBSE try-outs) and two others after the course (Master research projects) successfully designed and implemented ICT in IBSE activities with much independence and participation of pupils. Therefore, for the future optimisation of the course, we would add more-open IBSE experiences with or without ICT in Session 4 (intended for IBSE discussion). There are many IBSE activities in teacher journals and in international lesson materials, which can be adapted to use in Vietnamese classrooms. If one argues that this suggestion is too ambitious to be effective in realistic teaching conditions, then we suggest additional approaches with respect to the long-term effect of the course. We will intend a final half-day session for the participants to examine two or three most successful ICT in IBSE lessons in detail (e.g. watching the video of the try-outs) and discuss how to adapt these lessons to realistic school conditions (e.g. full class size, lack of equipment, limited time). Via this in-depth and scaling-up discussion, the participants would also share ingenious ways to deal with unfavourable teaching conditions and problems encountered while implementing ICT in IBSE lessons.

In the IBSE literature, it has often been assumed that pupils acquire inquiry skills just by engaging in inquiry. However, we think that explicit teaching is needed (Kirschner et al., 2006). This is an argument that has been extensively researched by nature-of-science researchers as well (e.g. Akerson et al., 2000). Van Merriënboer et al. (2002) formulated a model for teaching and learning complex skills in which they emphasise: teaching component skills separately does not necessary lead to mastery of complex skills. The main problem is in the integration of skills, so inquiry skills have to be practiced together in relatively open
investigations but with clear and explicit teacher feedback. Furthermore, a clearly designed learning path is needed to make sure that component skills and necessary procedural and conceptual knowledge get integrated properly. The gradual learning path and the explicit guidance should go well in the Vietnamese culture, while the final openness in investigation will be the difficult part of IBSE implementation. The desired cooperation between pupils could also be an element that goes well in the Vietnamese culture, although we also showed that pupils have to learn to cooperate effectively.

d) About the motivation objective

The motivation objective: participants are motivated to learn the ICT tools further and to try out more ICT in IBSE lessons with pupils.

Expected attainment level: the majority of the Vietnamese participants devised plans right after the course to learn and apply the ICT tools further. Additionally, a relatively long time after the course (a half year), about a half of the participants actually studied the ICT tools further and had tried out more ICT in IBSE lessons with pupils.

The data presented in Section 6.5.4 show that right after the course, most Vietnamese participants planned to study more about ICT tools (68%) and to apply these tools for their regular teaching, for participation in teaching competitions, for Master research projects, or for supervision of pupils’ science fair projects (77%). Half a year after the course, more than half of the participants had studied the ICT tools further (60%) and had taught more ICT and/or IBSE lessons (65%). Three participants got successful results with their Master research projects or pupils’ science fair projects, using the ICT tools. The participants looked back and still very appreciated the positive effects of the ICT in IBSE course, and so desired follow-up courses in order to discuss their recent ICT/IBSE teaching experience and to continue trying out new ICT in IBSE activities but with a whole class in realistic teaching conditions. Considering these analyses, we conclude that the Vietnamese ICT in IBSE course achieved its motivation objective at a slightly higher level than expected. The course was successful in building confidence in the participants and in preparing them for teaching ICT and IBSE lessons under realistic school conditions.

Active engagements of pupils in ICT/IBSE lessons and school boards’ encouragement with respect to innovation demands were stimulating factors that reinforced the participants’ motivation and made them interested in frequent incorporation of ICT/IBSE in their physics classes. According to MoET (2015), the educational reform in Vietnam from 2016 will place more emphasis on inquiry skills and ICT application in physics education. Moreover, qualifications for university entrance will be based on assessments of pupils’ learning during their secondary education and a national, final examination. The focus of assessments and examination will be shifted towards competency-based evaluations. Furthermore, pupils’ research and engineering projects will be included as a new integral part of the school curriculum, and in concert with this innovation, there have been science fairs for pupils across the country at school, provincial, and national levels. The pupil research project will be apart from traditional school subjects like physics, chemistry, and biology and aimed at pupils’ investigation of real-life problems in consultation with schoolteachers. These innovations will yield opportunities for sustainable ICT/IBSE incorporation, but will also present challenges for teacher preparation and training in this field. Considering its short duration and positive
achievement, the Vietnamese ICT in IBSE course can be a good point of departure for Vietnamese teachers to prepare for their relevant but challenging ICT/IBSE teaching in the future. We would like to recommend the course to be a) included formally in the Master programme on physics education and b) adapted for (re)education of teachers on ICT and IBSE within the reform of 2016 in Vietnam.

6.6.2 Conclusions and discussion about the pedagogical principles in the Vietnamese context

We presented and discussed the data about the implementation of the pedagogical principles and the support materials in Section 6.4. In this section, we finally conclude and discuss the validity of the pedagogical principles and the support materials in the Vietnamese context.

a) About the “one theory-practice cycle” principle

The one theory-practice cycle principle: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson in the classroom within the course.

The data presented in Sections 6.4.1, 6.5.3, and 6.5.4 show that all 22 Vietnamese participants completed one theory-practice cycle at the intended moments during the course scenario, and this resulted in intensive discussions about the ICT in IBSE try-outs in the final course session. Additionally, the ICT in IBSE lesson plans were of acceptable quality, and the participants appreciated the benefit of the classroom try-out. Furthermore, most of them gained motivation and were able to try out more ICT in IBSE lessons after the course. Therefore, we concluded that the “one theory-practice cycle” principle was implemented sufficiently, and it is valid in the Vietnamese context. The sufficient implementation of this principle directly contributed to the expected attainment level of the ICT in IBSE objective.

b) About the distributed-learning principle

The distributed learning principle: participants study in live sessions and carry out individual assignments on campus and in schools in between the sessions with support materials and in consultation with the course instructor and fellow participants.

The data presented in Sections 6.4.2, 6.5.2, and 6.5.3 show that the participants were satisfied with the format and timing for the live activities, and they invested more time outside live sessions than intended, 37.8 actual hours (SD=5.3) versus 30 anticipated hours. Most participants (16 out of 22) appreciated the distributed-learning scenario, which enabled their ownership of learning and their sufficient attainment of the “ICT mastery” and “ICT in IBSE” objectives. Considering these analyses, we conclude that the distributed-learning principle was implemented sufficiently, and it is valid in the Vietnamese context.

Before the actual implementation of the course, we predicted the constraints that the participants had to study new ICT tools with respect to acquiring sufficient ICT skills for ICT in IBSE try-outs in the first two weeks (see Section 6.1.4). In fact, scheduling individual assignments on campus proved to be a relevant adaptation of the distributed-learning principle. This had advantages of the ample contact time, the community of learners (i.e. a
specific characteristic of the Vietnamese context) and the direct and personalised support of the course instructor to compensate for the low ICT entrance of the participants within a limited duration (two weeks). The participants even achieved the ICT-mastery objective at the higher level than we expected. This finding led us to the conclusion that if the course is aimed at only the ICT-mastery objective, it does not need to be spread over a long period, but needs sufficient contact hours for participants to practice ICT skills with support materials and in consultation with each other and the course instructor. So, a compact Coach workshop with sufficient contact hours (and without assignments in between live sessions) can be suitable for the only ICT-mastery objective.

However, we aimed at the ICT in IBSE objective as the main goal for the ICT in IBSE course. This required a) sufficient time outside live meetings for the participants to think and design a good ICT in IBSE lesson plan and b) sufficient “spread” of the course to accommodate potential organisational barriers for the ICT in IBSE try-out in schools. The participants focussed on dealing with these organisational barriers and succeeded, but they could not sufficiently deal with implementation problems of the ICT in IBSE activities (see Section 6.5.3). Some of these problems could be reduced if the participants paid more attention in thinking through the lesson plan and/or practicing the lesson one time (with peers or some volunteer pupils) before the formal try-out. Therefore, in order to achieve a higher level of the ICT in IBSE objective, it is necessary to spread the Vietnamese course longer than five weeks. This was not allowed due to the regulations of the Master programme. However, with the research findings, we would probably convince the university to make it as an exceptional case. Please note that within the Master programme, the ICT in IBSE course was the only course that let the Master students try out their pedagogical ideas and learn from this.

c) About the depth-first principle

The depth-first principle: participants specialise in only one ICT tool (by choice) after having been introduced to the possibilities of the three ICT tools (i.e. data logging, video measurement, and modelling).

The data presented in Sections 6.4.3, 6.5.2, and 6.5.3 show that all Vietnamese participants followed the one-tool specialisation with a clear rationale and incentive for their choice of the specialised tool. Importantly, they were able to study their chosen tool in depth and gained the sufficient level of ICT mastery with that tool. Furthermore, right after the course, the majority of the participants (18 out of 22) felt confident that they would be able to learn the other tools by themselves. Half a year after the course, eight participants were able to transfer their experience of learning one tool in depth to learning other tools. So, we conclude that the depth-first principle was implemented sufficiently, and it is valid in the Vietnamese context.

Learning time for the ICT in IBSE course was prioritised for an in-depth study and application of one tool (one-tool specialisation) rather than broad study of all three tools at a more superficial level. However, the specialisation in only one tool did not prevent the participants from studying the other tools after the course. Obviously, deeper understanding of one ICT tool leads to better transfer for the whole ICT environment, so depth first - breadth later.
d) About the “ownership of learning” principle

The ownership-of-learning principle: participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives.

The data presented in Section 6.4.4 show that the participants were serious, responsible, and active in working in small groups and doing individual assignments with respect to the course objectives. They spent sufficient time for assignments and aimed at the best possible results. Especially, all participants were able to deal with insufficient school conditions for completing the ICT in IBSE try-out. This was predicted to be very difficult (see Section 6.1.2). The participants made use of their community of learners to help each other for preparing, implementing, and evaluating the ICT in IBSE try-outs. Importantly, it was not simply because they obediently carry out assignments, but also because they appreciated the relevance of ICT in IBSE methods and their role as teachers in finding suitable ways of using these innovative methods in current teaching situations in Vietnam. Considering these analyses, we conclude that the “ownership of learning” principle was implemented sufficiently, and it is valid in the Vietnamese context. Empowering the participants was indeed a good solution for insufficient school conditions for the ICT in IBSE try-out, and the community of learners proved to be very helpful.

e) About the support materials

The data presented in Sections 6.4.5, 6.5.2, and 6.5.3 show that the support materials were important for the participants to master one ICT tool in depth; to design and self-evaluate the ICT in IBSE lesson; and to pursue their self-tailored learning process within the course scenario. All of these support materials were translated from those, which were first developed and selected for the Dutch ICT in IBSE course and proved necessary and useful in the Dutch context. The translated versions also proved necessary and useful in the Vietnamese context. The translated materials were even used in a Master programme on physics education at another Vietnamese university, without the involvement of the researcher and still proved their effectiveness. These findings of the Vietnamese case study show that it is not always necessary to develop materials locally to have effective educational innovations. Instead, one can look around for existing materials and try to use them with certain adaptations. Moreover, the support materials were an independent part of the course design with specific role and value. With “independent”, we mean that the Coach support materials can be useful for other courses than the ICT in IBSE course, for example, for a course only focussing on Coach skills (TCK).

According to the participants, the Coach exemplary activities (i.e. exemplary ICT in IBSE materials) needed more adaptations to be suitable for the current physics curriculum, pupils’ background, and availability of equipment in Vietnam. The participants tended to make more use of the exemplary materials than the Dutch teachers and to use them as model activities to follow. Considering that most ICT in IBSE lessons of Vietnamese participants stayed within the guided discovery pattern, for future optimisation of the course, we should add more Coach exemplary activities with different patterns of inquiry, especially, a short, open investigation activity for each tool.
6.6.3 Transferability of the ICT in IBSE course in the Vietnamese context and remarks about application of IBSE in a hierarchical education culture

The Vietnamese context had specific characteristics, which were remarkably different from those of the Dutch and the Slovak contexts. We take the Dutch context to compare with the Vietnamese context:

- The Vietnamese participants were a mix of experienced teachers and fresh teacher-education graduates, who formed a close community of learners within the Master programme on physics education. The Dutch participants were student teachers.
- The Vietnamese version of the ICT in IBSE course had to be compressed in five weeks together with a parallel Master course, but many contact hours could be scheduled. The Dutch version had fewer contact hours, but these could be spread over a much longer period.
- The Vietnamese participants, before the course, had very little experience with the ICT tools and lacked practical experience with inquiry teaching and learning with or without ICT. The Dutch participants had more experience with the ICT tools, and most had some experience with independent investigations.
- Teaching conditions (incl. curriculum, equipment, pupils’ experience) in Vietnamese schools are poor and much less favourable for ICT in IBSE activities compared to those in Dutch schools.

The Vietnamese Master students participated in the course with little prior experience with ICT/IBSE as a learner and as a teacher, whereas they had to master ICT skills, to design an ICT in IBSE lesson, to implement it with pupils (for the first time ever) in insufficient school conditions within the limited duration. Additionally, the Vietnamese hierarchical culture embedded in the school practice might hinder introduction of IBSE in the classroom. These were indeed specific challenges for the Vietnamese ICT in IBSE course. In this context, to what extent was the course transferable? What were challenges to the application of IBSE in a hierarchical education culture? What are potential solutions for such challenges?

a) Adaptations of the course objectives and the pedagogical principles

The Vietnamese participants were expected to achieve a higher level of the ICT mastery (adopter-user, creator-user) than the Dutch participants (adopter-user level was also acceptable). This was because the Vietnamese participants had/have to be able to handle the ICT tool independently within and after the course. Meanwhile, the Dutch participants had/have sufficient support from school technical assistants (TOA) and ICT-experienced colleagues. Tailor-made ICT materials for Dutch curricula are plentiful. It was also because we could allocate in the Vietnamese context more contact time (30 to 60 hours) than in the Dutch context (9 to 12 hours) to ICT mastery (TCK). The distributed-learning principle was then adjusted to this expected attainment level, the low ICT entrance, the ample contact hours, and the compressed schedule due to the ICT in IBSE try-out requirement (see Section 6.1.3).

b) Strengths of the Vietnamese ICT in IBSE course

The course was successful in making the participants aware of educational benefits of the ICT tools and in bringing them from the non-user level to the adaptor-user, creator-user, or
The achievement of the expert level by half of the participants was far beyond our expectation. Additionally, the course made the participants aware of what IBSE involves in the classroom and enabled them to gain exposure to implementing an IBSE lesson with pupils. A nice first step towards IBSE within the constraints of curriculum and the teacher experience showed up as a few experienced-teacher participants generated ingenious ways to get their pupils involved in designing experiments in a typical Vietnamese verification laboratory (Figure 6.7). Furthermore, the course was also successful in building confidence and motivation in the participants and in preparing them for teaching ICT/IBSE lessons under realistic school conditions.

c) Weaknesses of the Vietnamese ICT in IBSE course

The Vietnamese course achieved its ICT in IBSE objective as predicted, but compared to the Dutch course, there was much more room for improvement with regard to this objective. Most Vietnamese participants had persistent problems with elaborating concrete IBSE lesson designs and with implementing IBSE intentions in the classroom environment (see Section 6.5.3) even when working with a small number of volunteer pupils. Most Vietnamese participants (82% of N=22) chose a topic and context limited to the curriculum and mainly verification activities, whereas the Dutch participants were more adventurous in selecting topics outside the formal syllabus (41% of N=29). Most Vietnamese participants (68% of N=22) intended to take control over the entire classroom activity through the guided-discovery lesson pattern, whereas for half of the Dutch ICT in IBSE lesson plans (50% of N=30), pupils were provided with more participation and independence in more-open inquiry patterns (e.g. guided inquiry, bounded inquiry, and open inquiry). Regarding particular inquiry skills operationalised in the lesson plan, the Vietnamese participants focussed more on pupils’ manipulations of equipment and software (2.1), whereas the Dutch participants placed more emphasis on pupils making hypothesis and prediction (1.2, 1.4) and explaining results (3.5) (compare Figure 6.8 and Figure 4.15 in Chapter 4). Indeed, it was difficult to get across the basics of IBSE implementation, even though the Vietnamese version of the ICT in IBSE course had many more contact hours in comparison with the Dutch version. The choices, which the Vietnamese participants made regarding their IBSE lessons, were not necessarily bad choices considering their experience and teaching conditions. However, we would like to see a bit more progress on the scale from closed to open investigations and more pupil involvement in the planning and interpretation phases of the ICT in IBSE activity.

d) Transferability of the ICT in IBSE course in the Vietnamese context

The adaptations to the Vietnamese context proved to be very necessary to make the Vietnamese ICT in IBSE course viable and effective and to fit the Master programme requirements. The application of the pedagogical principles, the course design, and the support materials went fine, and we achieved the course objectives in Vietnam, except that the teaching and learning of the IBSE component with ICT still needed considerable fine-tuning. This was influenced by not only the ICT in IBSE course but also the Vietnamese hierarchical education culture. These results confirmed external validity of the pedagogical principles and transferability of the ICT in IBSE course in the Vietnamese context.
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e) Challenges and potential solutions to the application of IBSE in a hierarchical education culture

Why should one want IBSE in Vietnam? Is that not imposing Western culture? Science is a body of knowledge, a set of tools for generating and validating knowledge (inquiry), and a multi-faceted view of nature (nature of science). Therefore, pupils regardless their culture should have some knowledge about research and experience with the process of inquiry. The Ministry of Education and Training of Vietnam supports this view, and they have included inquiry among its curriculum aims. In order to achieve this aim, pupils should experience inquiry themselves.

Already before the Vietnamese case study, we predicted some challenges to the participants’ application of IBSE in Vietnam such as IBSE inexperience of both the participants and their pupils and the dominant role of the participants as teachers in the classroom, which would conflict with the pupil-centeredness required in open investigations. After the case study, our predictions about these challenges were confirmed. Furthermore, we recognised Vietnamese teachers’ rather narrow interpretation of IBSE, and their lack of open inquiry experience. We also discovered IBSE-implementation problems such as the long derivations before IBSE (they could kill inquiry!) and the poor group management. Additionally, we realised that the dominant role of the teacher shows up not only in the Vietnamese school’s learning environment but also in the Vietnamese higher education culture. The dominant position of the course instructors in the discussion of lesson plans was contradicting IBSE to some extent. Please note that with the “one theory-practice cycle” and “ownership of learning” principles, the ICT in IBSE course stimulated and supported the participants to exercise an inquiry process of learning how to integrate ICT into IBSE (i.e. inquiry approach for teachers’ learning to teach inquiry to pupils).

So, what are potential solutions? For next use of the ICT in IBSE course, participants should work in small groups with a major role in reviewing lesson plans from fellow participants. Both the course instructor and participants should be involved in the review and feedback process as equal participants in a professional learning community. Additionally, issues like open inquiry experience and group management need explicit attention in the ICT in IBSE course. Open inquiry experience and IBSE teaching experience even need earlier attention in previous Master courses and in the undergraduate teacher-education programme. Within limited time, the ICT in IBSE course should focus on a few objectives to be effective: ICT mastery and ICT in IBSE integration. Furthermore, participants’ achievement through the course under the time constraints is just a good point of departure. More theory-practice cycles are needed for Vietnamese participants to gain more experience in thinking through inquiry objectives, designing IBSE instructions, adjusting these to particular pupils and classroom conditions, and figuring out subtle changes in such instructions, which can trigger minds-on inquiry while keeping the activity manageable. They should not only develop the skill of designing and implementing ICT in IBSE activities in current classroom conditions but also change their perceptions of what IBSE means.
Chapter 7 General conclusions and discussion

7.1 Brief overview

The aim of the present research was twofold. First, the objective was to design an effective short course, which – with some adaptations - will be effective in widely different teacher-education programmes. The course was aimed at preparing and supporting student teachers and teachers with diverse teaching experience to integrate ICT in inquiry-based science education (IBSE). The present research confined this integration to three constructional tools: data logging with sensors, video measurement, and dynamical modelling and the use of these tools in such a way that the lesson becomes an inquiry lesson in which pupils are involved to some extent in formulating aspects of experimental design and interpretation of results rather than only “doing” the experiment. "Short" was considered as a general time-constraint condition of the course in order to fit into overloaded pre-service programmes or in-service programmes. Second, this research was to investigate the validity of pedagogical principles, which were used to guide a) the design, implementation, evaluation, and optimisation of the course and b) the extent to which the course can be adjusted in the different settings in the Netherlands, Slovakia, and Vietnam. The pedagogical principles are at a higher level of abstraction and intended to be generalizable across educational and cultural contexts. The design research approach provided guidelines for and scientific reasoning behind this research and design process (Figure 7.1), which was guided by two research questions. First, what are characteristics of an effective, short course for Dutch student teachers to learn to apply the ICT tools in IBSE? Second, to what extent is the course applicable in different educational and cultural contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam)?

![Design and research process](image)

*Figure 7.1. The design and research process including an explorative phase and a cyclic-research phase with three case studies in the Netherlands (NL), Slovakia (SK), and Vietnam (VN).*

In this chapter, the two research questions are answered, and the basic design of the ICT in IBSE course and guidelines for adaptation in different contexts are discussed. After that, we reflect on the main findings concerning the pedagogical principles for teacher
education, mastering ICT skills (process, problems, and solutions), and inquiry teaching with ICT in different education cultures. Next, we reflect on the design research approach; measurement methods and instruments; and limitations of the research. Finally, we provide suggestions for future research.

7.2 Main findings, conclusions, and discussion

7.2.1 The first research question: basic design of the ICT in IBSE course

What are characteristics of an effective, short course for Dutch student teachers to learn to apply ICT tools for data logging, video measurement, and modelling in inquiry-based science education?

Course objectives, pedagogical principles, and support materials

To answer this question, based on the pedagogical considerations from the literature study (Chapter 2), we first elaborated the general aim of the course to the four objectives:

1. **Awareness objective**: participants become aware of educational benefits of the ICT tools in science education.
2. **ICT mastery objective**: participants master skills to operate the ICT tool.
3. **ICT in IBSE objective**: participants can design, implement, and evaluate an ICT in IBSE lesson.
4. **Motivation objective**: participants are motivated to continue studying the ICT tools and trying out ICT in IBSE lessons with pupils.

Taking into account these objectives, we studied the literature (Chapter 2) and defined the following four pedagogical principles:

1. **One theory-practice cycle**: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson within the course. Participants will apply the IBSE theory in a design for an ICT in IBSE lesson, which they will also try out in the classroom, self-evaluate, and report in the final session of the course.
2. **Distributed learning**: participants study in live sessions and carry out individual assignments in between the sessions with the support materials and in consultation with the course instructor. Learning time is distributed between live sessions and individual assignments, but is also carefully distributed over a longer period.
3. **Depth first**: participants are introduced to the possibilities of the three tools after which they specialise in only one ICT tool. Learning time is prioritised for an in-depth study and application of one tool (one-tool specialisation) rather than broad study of all three tools at a more superficial level, so depth first - breadth later.
4. **Ownership of learning**: participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives. The individual participants pursue their self-tailored learning process in which they make their own choices regarding the tool, the grade level, topic, and activity for their ICT in IBSE try-out with pupils.
After that, we operationalised the pedagogical principles in a concrete initial scenario of the course for Dutch student teachers and adapted it to the Dutch educational context and the post-graduate teacher-education programme. The Coach platform for data logging, video measurement, and modelling was used together with available support materials (i.e. Coach introductory, tutorial, and exemplary activities) and materials that we developed (i.e. forms for designing and self-evaluating the ICT in IBSE lesson) (see Chapter 3, Section 3.1.4).

**Implementation, evaluation, and optimisation of the ICT in IBSE course**

We implemented the ICT in IBSE course with 40 Dutch physics/chemistry student teachers spread over four sequential cycles and conducted the Dutch case study to evaluate and optimise the course. The course evaluation concerned implementation of the pedagogical principles, usefulness of the support materials, and attainment of the course objectives. For more detail about the evaluation framework and instruments for data collection and analysis, see Chapter 3, Sections 3.3 and 3.4. Among the four cycles, Cycles 1 and 2 were for fine-tuning of the course scenario. The course evaluation (incl. what did work, what did not work, and why) in Cycle 1 suggested revisions of the initial course scenario. These revisions were aimed at more faithful implementation of the course in Cycle 2 and with respect to many factors such as diversity of participants’ background, their technological and pedagogical problems during the course, and curriculum time for ICT in IBSE try-outs. Likewise, the Cycle 2 evaluation was guided by the course objectives and pedagogical principles and resulted in further optimisation of the course scenario (Figure 7.2). We achieved a faithful implementation of the four principles in Cycle 3. Consequently, in this cycle, summative effects of the Dutch version of the ICT in IBSE course were evaluated, and only minor suggestions were made for further optimisation. The robustness of the basic course design and the pedagogical principles were tested in Cycle 4 under routine implementation conditions without extra support of the researcher.

![Course objectives, pedagogical principles, and support materials](image)

*Figure 7.2. Optimisation of the ICT in IBSE course in the Dutch context through the three iterative cycles and robustness test of the Dutch ICT in IBSE course.*

**Answer to the first research question and basic design of the ICT in IBSE course**

Chapter 4 presents the entire Dutch case study, which resulted in an optimised and successful scenario (Figure 7.3) of the ICT in IBSE course (Cycle 3). Working in accordance with this scenario, the Dutch participants achieved the course objectives, also when the course was taught under the routine conditions (Cycle 4). The iterative evaluation and refinements of
the course confirmed the validity of the pedagogical principles in the Dutch context. The support materials proved necessary and useful for the sufficient implementation of the pedagogical principles and the satisfactory attainment of the course objectives. To conclude, the four course objectives, the four pedagogical principles, and the optimised scenario with the support materials establish the core characteristics and basic design of an effective short ICT in IBSE course for Dutch student teachers.

Figure 7.3 visualises the optimised scenario, illustrates the specific operationalization of the pedagogical principles in the Dutch context, and describes the time distribution for the three live sessions and two assignments and the plan on when to use which support materials and data-collection instruments. For more detail about the programme for the live sessions and the requirements for the individual assignments, see Chapter 4, Table 4.12.

Figure 7.3. The optimised scenario/basic design of the ICT in IBSE course in the Dutch context.

What is important about operationalization of the pedagogical principles?

On the way of arriving at the optimised scenario of the ICT in IBSE course as a complete educational product, we evaluated the course in cycles, recognised what did work, what did not work, and why, and refined the course scenario accordingly for the next cycle. These iterative evaluation and refinements of the course improved our understanding about what is important about operationalization of the pedagogical principles. In particular, timing was evaluated in iterative cycles, and rather big changes were made through two iterations of fine-tuning the course scenario. These changes involved distribution of the total study time across live sessions versus individual assignments (e.g. a full day instead of a half day for Session 1) and the extension of the time between the sessions (e.g. 9 instead of 3 weeks scheduled for the ICT in IBSE try-out). As a result, with basic mastery of the ICT tools initiated in Session 1, the Cycle-3 participants could continue studying the ICT tools outside live sessions and so, by themselves, learn sufficient ICT skills, which were necessary for preparing and teaching the ICT in IBSE lessons. All Cycle-3 participants completed their ICT in IBSE try-outs with satisfactory quality in the expanded time between sessions 2 and 3. To conclude, as far as distributed learning is concerned, fine-tuning the distribution of time and individual assignments is crucial.
Another main revision of the course scenario from Cycle 1 to Cycle 3 involved shifts from *online to direct consultation* and from *plenary to individual activities*, which were directly and pragmatically related to the individual assignments. For example, the focus of the instruction about IBSE was shifted from a plenary presentation plus discussion to an individual exercise on how to change a cookbook laboratory to become more inquiry. The Cycle-3 participants had to a) decide which tool to specialise in *before* the course and b) start designing the lesson plan right after Section 1 in order to be able to consult the course instructor about their own lesson plans in Session 2. These shifts enabled the instructor to provide *direct and personalised support* to a) troubleshoot TCK problems of their Coach activities (see Section 7.3.2) and b) improve the lesson plans before the classroom try-outs. During the course, participants had the freedom and responsibility to select what to learn and how to learn it with respect to the course objectives, but they were not left on their own. *Personalised support* (in live meetings and via emails) and *sense of direction* (via explicit support framework plus assignment tracking and stimulation) are crucial factors to ensure effectiveness of independent learning. These factors create a balance between *much freedom of choice and appropriate guidance*, which is essential to establish *ownership of learning*.

### 7.2.2 The second research question: adaptation of the basic design of the ICT in IBSE course in different contexts

*To what extent is the ICT in IBSE course applicable in different educational and cultural contexts of pre- and in-service teacher education in different countries?*

To answer this question, we adapted and implemented the ICT in IBSE course in Slovakia and Vietnam to test transferability of the course design and generalizability of the pedagogical principles to different contexts. The Slovak and Vietnamese contexts were deliberately chosen for this test, because these were remarkably different from the Dutch context (Table 7.1).

#### The Dutch, Slovak, and Vietnamese contexts

*About participants:* the Vietnamese participants were a *mix of experienced teachers and fresh teacher-education graduates*, who had been studying together in the fulltime Master programme on physics education for two years as a *close community of learners*. The Slovak participants were a *mix of teachers of physics, chemistry, biology, and geography* with *diverse teaching experience*, varying from 1 to 33 years of teaching. The Dutch participants were a *mix of physics and chemistry student teachers*, who were either *fresh master graduates or second career graduates*; their ages varied from 23 to 55.

*About scheduling requirements:* the Dutch course was limited to 28 hours of total study time, but it could be spread over 11 weeks. The Vietnamese course had to be compressed in 5 weeks to fit in a typical term period together with a parallel Master course, but almost all 60 hours could be scheduled for live activities on campus. The Slovak case had the least constraints, regarding both the total study time (40 hours) and “spread” of the course (15 weeks).

*About school conditions* (e.g. curriculum time, teacher preparation time, national examinations, teacher autonomy, pupils’ experience with ICT/IBSE, availability of equipment and software), the extent to which school conditions are favourable for ICT in IBSE teaching was remarkably different among the three countries. The Dutch school conditions were not
excellent but sufficient, whereas the Slovak school conditions were insufficient, and the Vietnamese conditions were very poor. In the Netherlands, the curriculum has been innovated in the direction of ICT and IBSE incorporation for about 30 years, and schools are now reasonably well equipped with ICT tools. IBSE is not common in the classroom; it is still an innovation rather than routine. However, the compulsory pupils’ research project is a strong innovation that stimulates open inquiry learning of pupils. In contrast, Vietnam is going to reform the educational system with regard to ICT and IBSE incorporation in the curriculum, starting from 2016. ICT tools for data logging with sensors, video measurement, and dynamical modelling are not available in Vietnamese schools yet. IBSE is rare in the Vietnamese classroom, and Vietnamese pupils have almost no experience with inquiry-based learning and laboratory activities with and without ICT.

Table 7.1. Differences among the Dutch, Slovak, and Vietnamese contexts for the ICT in IBSE course.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Dutch context</th>
<th>Slovak context</th>
<th>Vietnamese context</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Number</td>
<td>40 student teachers</td>
<td>66 experienced teachers</td>
<td>22 master students</td>
</tr>
<tr>
<td>• Background and age</td>
<td>Mix of fresh-master &amp; second-career graduates; physics &amp; chemistry Age: 23 to 55</td>
<td>Mix of physics, chemistry, biology, &amp; geography teachers Age: 23 to 55</td>
<td>Mix of fresh graduates &amp; experienced teachers, Physics Age: 23 to 31</td>
</tr>
<tr>
<td>• Teaching experience</td>
<td>1 to 5 years, 83% at first-year teaching</td>
<td>1 to 33 years, 19 years on average</td>
<td>0 to 9 years, 23% with no teaching</td>
</tr>
<tr>
<td>• Entrance level of ICT skills</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scheduling requirements</th>
<th>Dutch context</th>
<th>Slovak context</th>
<th>Vietnamese context</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Programme</td>
<td>Post-graduate teacher education</td>
<td>Accredited professional development</td>
<td>Master in physics education</td>
</tr>
<tr>
<td>• Total study time of the course</td>
<td>28 hours</td>
<td>40 hours</td>
<td>60 hours</td>
</tr>
<tr>
<td>• “Spread” of the course</td>
<td>11 weeks</td>
<td>15 weeks</td>
<td>5 weeks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching conditions</th>
<th>Dutch context</th>
<th>Slovak context</th>
<th>Vietnamese context</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Availability of the ICT tools</td>
<td>sufficient available in most schools</td>
<td>limited</td>
<td>none</td>
</tr>
<tr>
<td>• Pupil experience with ICT</td>
<td>sufficient pupils have ever used Coach/similar software</td>
<td>insufficient ICT is starting to be introduced</td>
<td>none</td>
</tr>
<tr>
<td>• Pupil experience with IBSE</td>
<td>insufficient certain experience with laboratory but less with IBSE</td>
<td>poor a little experience with laboratory but very limited with IBSE</td>
<td>none</td>
</tr>
<tr>
<td>• IBSE in curriculum</td>
<td>explicit and required</td>
<td>starting to be required</td>
<td>in new 2016 curriculum</td>
</tr>
<tr>
<td>• Teacher autonomy</td>
<td>high</td>
<td>moderate</td>
<td>low</td>
</tr>
</tbody>
</table>

Although most Vietnamese and Slovak participants were experienced teachers, their ICT mastery entrance level was low. The Dutch participants had more experience with the ICT tools. They took more freedom to deviate from textbook, and they had greater autonomy to decide their own lesson objectives and teaching methods to achieve the curriculum goals.
(incl. inquiry and ICT goals). However, they lacked teaching experience, especially classroom management skills. All three groups of participants had learned about theory of IBSE before the course, but they lacked practical experience with inquiry teaching with or without ICT, so ICT in IBSE teaching as the general aim of the course was challenging for them. This leads to time constraints as a general boundary condition of the ICT in IBSE course. For all three versions of the course, diversity of participants and time constraints were challenging contextual factors, but these factors manifested themselves in each context differently.

Adaptation of the basic design of the ICT in IBSE course in different contexts

Taking into account the specific context of the ICT in IBSE course in Slovakia and Vietnam, we redefined expectations about attainment of the course objectives and adapted the operationalization of the pedagogical principles to produce the local course scenario (Table 7.2). In particular, following demands from Slovak schools, the ICT-mastery objective of the Slovak course was extended to all of the three ICT tools. The Slovak participants were expected to achieve basic skills with all three tools and to attain the creator-user level for a specialised tool by choice (this expectation was higher than that for the Dutch participants). Accordingly, the Slovak participants had to acquire sufficient skills with all three tools before specialising in one tool for designing and teaching the ICT in IBSE lesson (adaptation of the depth-first principle). Furthermore, taking the Slovak participants’ low entrance level of ICT skills into account, we allocated 4 out of 5 live sessions and 3 out of 4 individual assignments for them to master the expected ICT skills. In short, we focused on the ICT-mastery objective in the first and much-larger part of the course (adaptation of the distributed-learning principle) (Table 7.2).

About the Vietnamese case, the Vietnamese participants were expected to achieve a higher level of the ICT mastery (adopter-user, creator-user) for their specialised tool than the Dutch participants were (adopter-user level was also acceptable). This was because the Vietnamese participants had to be able to handle the ICT tool independently for ICT in IBSE teaching within and after the course. On the other hand, most Dutch participants had sufficient support from school technical assistants (TOA) and ICT-experienced colleagues, and there were many ICT activities available suitable for the Dutch curriculum. Fortunately, we could allocate more contact time in Vietnam (Table 7.1) to ICT mastery (TCK). The distributed-learning principle was then adjusted to this expected attainment level, the low ICT entrance, the ample contact hours, and the compressed schedule due to the ICT in IBSE try-out requirement. In particular, we scheduled most of the individual assignments on campus (21 out of 30 assignment hours) for the participants to gain benefit from direct and personalised support from the course instructor and each other. Additionally, many more contact hours (incl. assignments on campus) were scheduled in the first two weeks (39 out of 54 hours) for the participants to study one chosen tool in depth, and so timely master ICT skills (Table 7.2) that were needed for designing and teaching the ICT in IBSE lesson within the remaining three weeks.

The operationalization of the “ownership of learning” principle was the same for all three cases and in concrete ways: the one-tool specialisation by choice, the freedom of choice for the ICT in IBSE lesson, and the focus on individual and group work rather than plenary
activities. The Vietnamese course took slightly more control over participants than the two others did, due to its first compact ICT-mastery part, but the amount of control was still little. About the operationalization of the “one theory-practice cycle” principle, it was the same for all three cases as the ICT in IBSE try-out was a main assignment. Unlike in the Dutch and Vietnamese courses, the try-out was optional in the Slovak course and mainly prepared in the fifth (last) session and via fourth (last) individual assignment (Table 7.2). However, it was strongly encouraged and scheduled in about half of the duration of the Slovak course (7 out of 15 weeks, Table 7.2). About the support materials, almost all remained the same for the three versions of the course, except for translations into the local languages. The Slovak course used extra ICT in IBSE materials from the ESTABLISH project, and so the ESTABLISH form for the ICT in IBSE lesson plan was used instead of the similar form used in the Dutch and Vietnamese courses. The online platform was only used in the Netherlands and Slovakia and not in Vietnam because the Vietnamese participants had ample contact time (54 out of 60 hours for live sessions and for individual assignments on campus) where they could get direct assistance and support materials from the course instructor.

Table 7.2. Differences in operationalization of the pedagogical principles in the different versions of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam.

<table>
<thead>
<tr>
<th>Operationalization of the depth-first principle</th>
<th>Dutch version</th>
<th>Slovak version</th>
<th>Vietnamese version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1. Studying possibilities</td>
<td>3 tools</td>
<td>3 tools</td>
<td>3 tools</td>
</tr>
<tr>
<td>Stage 2. Practicing basic ICT skills</td>
<td>1 tool</td>
<td>3 tools</td>
<td>1 tool</td>
</tr>
<tr>
<td>Stage 3-5. Designing, trying out, &amp; evaluating an ICT in IBSE lesson</td>
<td>1 tool</td>
<td>1 tool</td>
<td>1 tool</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operationalization of the distributed-learning principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total study time</td>
</tr>
<tr>
<td>*spent for live sessions</td>
</tr>
<tr>
<td>*scheduled for individual assignments</td>
</tr>
<tr>
<td>“Spread” of the course</td>
</tr>
</tbody>
</table>

First part dedicated to the ICT-mastery objective

<table>
<thead>
<tr>
<th>*of the live hours</th>
<th>50%</th>
<th>80%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>*of the assignment hours</td>
<td>25% (all in distance)</td>
<td>75% (all in distance)</td>
<td>60% (all in contact)</td>
</tr>
<tr>
<td>*of the course duration</td>
<td>2 weeks</td>
<td>8 weeks</td>
<td>2 weeks</td>
</tr>
</tbody>
</table>

Second part dedicated to the ICT in IBSE objective

<table>
<thead>
<tr>
<th>*of the live hours</th>
<th>50%</th>
<th>20%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>*of the assignment hours</td>
<td>75% (all in distance)</td>
<td>25% (all in distance)</td>
<td>40% (almost all in distance)</td>
</tr>
<tr>
<td>*of the course duration</td>
<td>9 weeks</td>
<td>7 weeks</td>
<td>3 weeks</td>
</tr>
</tbody>
</table>
Attainment of the ICT in IBSE course in different contexts: Answer to the second research question and discussion

Across the three case studies, the awareness and motivation objectives of the ICT in IBSE course were achieved as expected. The participants could enumerate relevant benefits of the ICT tools, and they devised plans and actually continued studying the ICT tools and teaching ICT in IBSE lessons after the course. About the ICT-mastery objective, all three groups of participants were able to operate the Coach tool fluently after the course. Compared with the Dutch participants, the Vietnamese participants attained a higher mastery level for the specialised tool, and the Slovak participants achieved a similar ICT mastery but with all three ICT tools. This shows effectiveness of the many more contact hours with direct and personalised support scheduled for the ICT-mastery objective (Table 7.2) in a) compensating for the low ICT entrance of the Slovak and Vietnamese participants and b) enabling them to achieve the expected ICT mastery.

About the ICT in IBSE objective, all three groups of participants were able to design and realise acceptable ICT in IBSE lessons considering their teaching conditions and their inexperience with inquiry teaching with ICT. The Dutch participants could design and realise better ICT in IBSE lessons than the Slovak and Vietnamese participants. Many Dutch participants were able to engage pupils in designing experiments or models and predicting and interpreting results as expected. Meanwhile, the Slovak and Vietnamese participants focused too much on pupils’ execution of experiments or models (manipulation of equipment and software) and did not sufficiently involve pupils in moving back and forth between the physical and theoretical worlds (manipulation of ideas and concepts). Most Slovak and Vietnamese participants intended to take control over the entire classroom activity through plenary systematic explanations and/or prescriptive worksheets for the group work (patterns of interactive demonstration and guided discovery). In contrast, in half of the Dutch ICT in IBSE lesson plans, pupils were required to take a larger role in conception, planning, and interpretation of the experiment/model in more-open inquiry patterns (i.e. guided inquiry, bounded inquiry, and open inquiry) (Figure 7.4). All three groups of participants had trouble to operationalise inquiry objectives in the activity specifications (lesson plan). They also encountered serious problems in implementing inquiry teaching with ICT. There were many deviations between intended and actual ICT in IBSE lessons, and these resulted from reasons such as shortcut of intended inquiry opportunities; tasks that were too demanding; over ambitious timing; and ineffective communication with pupils. Importantly, Dutch, Slovak, and Vietnamese participants were able to recognise deviations and problems in the evaluation of their ICT in IBSE try-outs and were able to suggest relevant revisions of their lesson plans for future use.

In short, the three versions of the ICT in IBSE course achieved the four objectives to the pre-determined acceptable level (for more detail, see the conclusion sections 4.5.1, 5.6.1, and 6.6.1). Therefore, we conclude that the basic design of the ICT in IBSE course was effective, practical, and transferable in the different educational and cultural contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam). This basic design is a concrete practical contribution of the present research to teacher education. The local version of the course in each country along with the support
materials constitute a practical reference for teacher educators, who are going to prepare similar ICT/IBSE courses for pre- or in-service teacher education.

Figure 7.4. Percentage of ICT in IBSE lesson plans (of Dutch, Slovak, and Vietnamese participants) categorised in certain patterns of inquiry teaching.

Based on the pedagogical principles, we operationalised the Dutch version of the ICT in IBSE course and achieved the course objectives with the diverse group of the Dutch student teachers within the limited contact hours, although we would have liked better results on the ICT in IBSE part. Furthermore, we operationalised and adapted the pedagogical principles in the Slovak and Vietnamese versions in contexts that were remarkably different from each other and from the Dutch context. In these new contexts (Table 7.1), low ICT entrance of the Slovak and Vietnamese participants, diversity of participants (Slovak case: diverse background, age, and teaching experience), time constraints (Vietnamese case: course duration compressed in five weeks) were specific challenges for the ICT in IBSE course. Our research data show that we achieved the course objectives in Slovakia and Vietnam, except that for the ICT in IBSE part there was still much room for improvement. These results confirmed external validity and so generalizability of the pedagogical principles. The pedagogical principles are valid in a) providing the framework for designing, implementing, evaluating, and optimising the ICT in IBSE course in a specific context and b) guiding the adaptation of the basic design of the ICT in IBSE course in remarkably different contexts. Among the four principles, the “depth-first” and “one theory-practice cycle” principles are crucial, as without them the ICT mastery and ICT in IBSE objectives cannot be reached. The “ownership of learning” and “distributed learning” principles provide the dials to fine-tune the course to heterogeneous groups of participants (ownership of learning) and to specific time-constraint conditions (distributed learning) with respect to the course objectives. Overall, the four pedagogical principles are valid and should be used as a complete set to establish an effective, robust, and transferable design of the ICT in IBSE course. All of them should be considered when adapting the course to a different context.

Pedagogical guidelines for adapting the course to a different context

How should the pedagogical principles be tuned to the local context?

As far as adaptation of the basic design of the ICT in IBSE course in a different context is concerned, the “one theory-practice cycle” principle should not be changed. Instead, the “depth first” and “distributed learning” principles can be adjusted by the course instructor to
some extent to the specific context, considering the entrance level and other characteristics of the participants and the scheduling requirement. The “ownership of learning” principle has to be enabled to provide a dial for participants to self-tune the course to their own interest and ability as they can choose the ICT activities, topics, and level of difficulty. We explain and elaborate these guidelines in the paragraphs that follow.

In the Slovak case, although the try-out was optional and mainly prepared in the last session and via the last assignment (Table 7.2), the Slovak course still ended up with a good number of participants who could complete the ICT in IBSE try-out (20 out of 27). Moreover, the try-outs were of satisfactory quality for the TCK aspect (ICT and content knowledge). Consequently, the lack of ICT equipment and software in Slovak schools should not have been the reason to schedule the try-out as optional. Even in more-constrained school conditions, the compulsory try-out was fulfilled to an acceptable extent by all Vietnamese participants, who were at similar ICT/IBSE entrance level as the Slovak ones. Additionally, almost all of the Dutch, Slovak, and Vietnamese participants appreciated the ICT in IBSE try-out within the ICT in IBSE course and found it very relevant for their professional development. Therefore, the try-out as a mandatory requirement should not be changed when adapting the course to a different context. To ensure the fulfilment of one theory-practice cycle and the acceptable quality of the ICT in IBSE try-out, our research findings suggested the following considerations. First, there should be sufficient time for designing and scheduling the classroom try-out. The three weeks for designing and teaching the ICT in IBSE lesson, as in the Vietnamese case for example (Table 7.2), proved to be insufficient, considering many IBSE implementation problems in the classroom. Second, designing the ICT in IBSE lesson plan needs to start at the beginning of the course or soon after, so participants will have opportunities to consult the course instructor in live meetings to improve the lesson plans before their implementation. In the Slovak case, the ICT in IBSE try-outs would have been of better quality for the IBSE aspect, if the lesson plans had been commented on properly by the course instructor beforehand. Participants should experience the try-out lesson as a good experience for motivational reasons, so the course instructor’s check of the lesson plan is important.

For all three cases, the “ownership of learning” principle was operationalised as participants’ freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives. Ownership of learning was first considered and used as a method not only to deal with the diversity of participants (by freedom of choice) but also to empower participants so that they can choose and adjust activities to their pupils, classrooms, and schools. This method worked out in all three cases, and ownership of learning turned out to be a learning outcome, which resulted from sufficient implementation of the other principles. Participants’ ownership of learning together with their awareness, confidence, and motivation after the course enabled them to continue studying and applying ICT/IBSE for a relatively long time afterward. Research findings from the Dutch case study confirmed that “personalised support” and “sense of direction” are crucial in ensuring effectiveness of independent learning of participants during the ICT in IBSE course. From the Slovak and Vietnamese cases, we realised that a community of learners can stimulate learning ownership of its members. It helps participants to study ICT tools more quickly (all three cases), to deal with insufficient conditions for the ICT in IBSE try-out
(Vietnamese case), and to encourage each other to incorporate ICT in IBSE in the classroom through sharing lesson materials and teaching experiences (Slovak case). In short, when adapting the course to a different context, the “ownership of learning” principle has to be enabled. To ensure participants’ ownership of learning, personalised support and sense of direction are determinants, and learning community is a stimulating factor.

Regarding the depth-first principle, the participants’ in-depth learning has two aspects. The first involves participants learning not only to manipulate but also to apply the tool in an ICT in IBSE lesson. This aspect reflects the essence of the learning in depth, so it was applied for all three versions of the ICT in IBSE course. The second aspect involves potential stages of this in-depth process:

- **Stage 1.** Studying possibilities of the ICT tools
- **Stage 2.** Mastering basic skills to operate the ICT tool(s)
- **Stage 3.** Designing the ICT in IBSE lesson that makes use of the ICT tool
- **Stage 4.** Teaching the ICT in IBSE lesson with the ICT tool
- **Stage 5.** Evaluating the ICT in IBSE try-out with the ICT tool

At the beginning of the course, participants study all three tools at the first stage(s) (acquaintance and orientation phase). After that, they specialise in one of the three ICT tools (by choice) at the remaining stages (specialisation phase). The choices of at which stage to start specialising in only one tool and how much time to allocate for the acquaintance and orientation phase with all three tools should be based on the focus of the course (i.e. ICT mastery for all three tools or ICT in IBSE classroom experience), the entrance level of participants, and the scheduling requirement (Table 7.2).

The distributed-learning principle concerns the distribution of time between live sessions and assignments and the scheduling of course sessions and assignments across weeks or months. According to this operationalization, the individual assignments outside live sessions are considered as important as the live activities, and so time and individual assignments must be distributed sufficiently. Applied in all three cases, time was distributed and the individual assignments were focussed as a crucial component of the course. However, how much time for live sessions, how much time for individual assignments, and whether the assignments are carried out on campus or at home varied considerably among the three cases. Obviously, one needs analysis of the course focus, the participant’s entrance level, and the scheduling requirement to make a proper scenario for the course as far as distributed learning is concerned. An online platform is needed as a component of the distributed-learning scenario when the course is spread over a long period (the Dutch and Slovak cases). However, this component can be left out in a context where sufficient contact hours can be scheduled (the Vietnamese case).

The adjustment with distributed learning and depth-first makes the first flexible phase: ICT mastery, which can be lengthened (Slovak case) and compressed (Vietnamese case) in order to compensate for the low ICT entrance, accommodate diversity of the participants, and align their activities, assignments, and efforts with the intended attainment of the ICT mastery objective (Table 7.2). Such ICT mastery attainment is necessary for the participants to be able to a) design and teach the ICT in IBSE lesson during the last phase: ICT in IBSE and b) continue studying and using the ICT tools after the course. Through the Vietnamese and
Dutch case studies, we realise that it is not necessary to spread the first phase over a long period for the ICT-mastery objective; one to two weeks are sufficient. However, it needs sufficient contact hours for participants to practice ICT skills with support materials and apply such skills in modifying, developing, and troubleshooting the Coach activity in consultation with each other and with the course instructor (the Dutch case: a full day for the first session instead of a half day; the Vietnamese case: individual assignments on campus). Comparing the Dutch case with the two other cases, we suggest that participants should be asked to start specialising in one tool soon to practice ICT skills (e.g. halfway the first session) in case of limited contact time (e.g. 6 hours in the Dutch case as a minimum). The participants might just get over threshold to be able to continue studying the tool on their own (the first individual assignment at home). They might attain minimum ICT mastery for designing and teaching the ICT in IBSE lesson. If having more contact hours (e.g. Vietnamese case: about 30 hours in contact), participants can be asked to study one tool in depth for a longer period with direct support to achieve higher ICT mastery for one specialised tool. With more contact hours (e.g. the Slovak case: 20 hours per four live sessions), the course can schedule the participants to master basic skills with all three tools before their one-tool specialisation. In this way, the pre-scheduled amount of contact time can influence the expected attainment of the ICT-mastery objective of the ICT in IBSE course in a particular context.

On the other hand, the study time for the ICT in IBSE objective needs to be distributed, and so the course duration (stages 3, 4, and 5) needs to be spread out sufficiently. In its first cycle, the Dutch course with 9 contact hours was spread over five weeks, which turned out to be insufficient for the participants to design the ICT in IBSE lesson plan outside live sessions and especially to tackle organisational barriers for the ICT in IBSE classroom try-out (e.g. finding curriculum time and opportunity for the lesson). The Vietnamese course also took place for five weeks, but with many contact hours on campus, preparation of sufficient ICT skills and the ICT in IBSE lesson plan was accelerated in the first two weeks. Consequently, the Vietnamese participants could focus on dealing with such organisational barriers and succeeded in completing the ICT in IBSE try-out with acceptable quality. However, they could not deal sufficiently with implementation problems of the ICT in IBSE activities. Moreover, almost all Vietnamese participants chose a topic and context limited to the curriculum and mainly activities to verify familiar formulas or to measure constants. A few participants spent considerable time to derive formulas first, while the derivations were in the textbook. With their try-outs with small pupil-groups and enough ICT facilities outside regular lessons, they should have provided more-open activities for pupils regarding topics, contexts, and some involvement of pupils in design and interpretation rather than merely execution of experiments. These problems of the Vietnamese participants could be reduced, if they paid more attention in thinking through the lesson plan and if they had enough “breaks” away from their tight schedule within the compact time in order to generate creative but viable ideas for their ICT in IBSE lesson. These findings and interpretation drive us to the conclusion that five weeks can be a minimum “spread” to realise distributed learning with respect to acceptable ICT in IBSE try-outs within the course. Under this minimum condition, sufficient contact hours (about 60 hours) and direct and personalised support need to come in to make a proper distributed-learning scenario. In order to achieve a higher level of the ICT in IBSE
objective, it is necessary to spread the course longer than five weeks. Please note that even with a longer duration to be scheduled, there are still other problems concerning ICT in IBSE try-outs, for example, participants’ inexperience with IBSE teaching with and without ICT and possible limitations for IBSE implementation in an education culture (see Section 7.3.3).

**General conclusion: basic design and guidelines for adaptation in a different context**

The present research concluded with a basic design of an effective short ICT in IBSE course (incl. the four course objectives, the four pedagogical principles, and the support materials) as an educational product, which is applicable and transferable in remarkably different contexts. Among the course objectives, the ICT-mastery objective can be achieved in a compressed duration with sufficient contact hours, whereas attaining the ICT in IBSE objective needs to be distributed sufficiently. The support materials proved necessary, useful, and robust in different contexts. This finding shows that it is not always necessary to develop materials locally to have effective educational innovations. Instead, with certain adaptations one can use existing materials. The pedagogical principles are valid and generalizable; these provide not only the framework for implementing, evaluating, and optimising the course in a specific context but also guidelines for effective adaptation of the course in a different context.

This pedagogical framework and these guidelines help to define certain changes of the basic design with respect to different variables of the new context such as higher expectation about the course outcomes, more contact hours, longer duration, or lower entrance of participants. This leads us to metaphorise the ICT in IBSE course as a machine, which can be taken to and operated in different places where conditions are different. Different users may want to use it with slightly different aims. So how can the users adjust and operate the machine? The machine includes a set of “pedagogical principles with a few additions for variations to be concerned” as multilevel switch, auto-tuning dial, and manual dial for adjustment. The machine comes with an operating manual about how to adjust it to the local setting and different aims. With this metaphor, the “one theory-practice cycle” principle is not an on-off option; it must always be on. The “ownership of learning” principle is as an auto-tuning dial. “Auto-tuning” means that the course instructor first provides participants with freedom of choice and appropriate guidance (learning ownership enabled by the course instructor). Next, the individual participant takes initiative to tailor and pursue her or his own learning process (learning ownership self-tuned by participants). The “depth first” principle is as a multilevel switch for the one-tool specialisation. It can be switched on right after introduction of the ICT tools (the Dutch and Vietnamese cases). It can also be switched on after practicing all three tools and before designing the ICT in IBSE lesson (the Slovak case). The “distributed learning” principle is as a manual dial, which the course instructor (user of the machine) can adjust incrementally a) to provide more time for TCK learning at the start or b) to stretch the time distribution to allow for maturation of the ICT in IBSE lesson plan and adaptation to school conditions and schedules at the end. After pre-setting the machine at certain switch/dial levels, the user lets it operate and observes how it functions. The observation will help her or him to refine a suitable level for each switch and dial for next use.
There were different instructors involved in different versions of the course in different languages and countries. However, the course outcomes in the three different contexts were comparable. This resulted from the fact that the same pedagogical principles and support materials were applied, and this indicated that the effectiveness of the course was not much dependent on the choice of the course instructor. In addition, Coach as an educational product originated in the Dutch educational system proves to be applicable in other systems. The presentations in this dissertation are based on working with the Coach platform, but the experiences and solutions may be easily transferrable and valid for other ICT platforms.

It is common practice that each teacher education programme invents its own wheels. Our research outcomes through the development/adaptation, implementation, and evaluation of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam indicate that with careful design and well-chosen pedagogical principles, courses and other educational products could be fine-tuned and shared. The fifth Dutch ICT in IBSE course and the second Vietnamese ICT in IBSE course were implemented by the local course instructors after the research project without any involvement of the researcher. The third Slovak ICT in IBSE course is planned within a new large-scale national project, which is aimed at implementation of ICT tools across science subjects in Slovakia. The Dutch ICT in IBSE course (implemented with five batches already) is unique, since it is the only teacher-education course offered by Dutch universities together, as far as we know. The Vietnamese ICT in IBSE course is unique as it is the only Master course of which design and materials were entirely developed outside the university. These institutionalisations do not happen often for general educational projects. These show not only the practical relevance of the basic design of the ICT in IBSE course for different educational and cultural contexts of pre- and in-service teacher education, but also suggest the possibility to have more-productive standardisation among teacher education courses.

7.3 Reflection on the findings

7.3.1 Implications of “one theory-practice cycle” and “depth first” principles

The present research has proved validity and generalizability of the pedagogical principles, and so confirmed the literature from which these principles stem (see Chapter 2, Section 2.4.2). The findings about what is important about operationalization of the pedagogical principles and how the pedagogical principles should be tuned to the local context are a theoretical contribution to the literature. Like the basic design of the ICT in IBSE course, each pedagogical principle as such is an educational product. Teacher educators, who intend to develop a new teacher education course, but not on ICT in IBSE topics, might not find the basic design of the ICT in IBSE course useful, but they might find, for example, the “one theory-practice cycle” or “depth first” principles appropriate. Consequently, they adopt these ideas for their own course design. Therefore, the pedagogical principles have both theoretical and practical relevance and are worthwhile to be recommended for future research and for application in educational practice. In the following paragraphs, we discuss implications of the “one theory-practice cycle” and “depth first” principles.
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There are often complaints from beginning teachers that the theory and example practices that they have learned at the university are relatively disconnected from their teaching practices in the school. When they try to implement innovative methods in their classrooms, they run into different kinds of troubles, which are often caused by yet insufficient classroom management. This issue is often called the “theory-practice gap” or “theory-practice divide” in teacher education (Korthagen, 2010). The ICT in IBSE course prepares its participants with both theory and school practice. The classroom try-outs of ICT in IBSE methods are stimulated, prepared, and discussed in live sessions at the university. The Dutch and Vietnamese versions of the course were nice examples of having objectives of a teacher-education course and taking them all the way to the classroom for implementation, followed by evaluation of the outcomes (process and product). Importantly, satisfactory outcomes and long-term effects of the course with regard to ICT in IBSE teaching showed up and resulted from this theory-practice cycle. This further suggests the application of the “one theory-practice cycle” principle in other elements of the teacher education programme in the Netherlands and in the Master programme on physics education in Vietnam. One would have to identify a small number of crucial “practices” and organize theory-practice cycles for those. Sufficient incorporation of this principle in such programmes can contribute to reducing potential “theory-practice gap” problems of the graduates.

We first chose the depth-first principle because of the “ICT mastery” and “ICT in IBSE” objectives. In the Dutch and Vietnamese cases, the participants were asked to specialise in one tool right after having been introduced to the possibilities of all three tools, due to the time constraints and the focus of the local version of the course on the ICT in IBSE try-out. The risk was that the participants might not be able to study other tools on their own. Findings from the Dutch and Vietnamese case studies, however, show that the specialisation in only one tool did not prevent the participants from studying the other tools. Most Dutch and Vietnamese participants could fulfil the one-tool specialisation and were motivated and able to study other tools in a half to two years after the course. Obviously, deeper understanding of one ICT tool has surplus value compared to partial understanding of all three tools, and it leads to better transfer to the whole ICT environment. This reinforces a unique feature of Coach: all three ICT tools are integrated in the same learning environment. When users get deeper understanding of one Coach tool, they become more confident, get a better grasp of the Coach platform as a whole, and get used to the similarity among the three Coach tools. It takes much less effort to learn a second Coach tool than to learn the first Coach tool. This feature is also helpful for pupils in learning the Coach tools, and the depth-first principle can be applied for pupil learning of ICT skills as well.

This successful experience further suggests the application of the depth-first principle as part of a solution for “overloaded contents” and “workload pressure” problems (e.g. too much knowledge to learn within in a limited time), about which Dutch student teachers commonly complain. Suppose a teacher-education course having ultimate objectives related to several domains, the teacher educator can provide orientation on the entire area and then assign student teachers to specialise in a domain. For example, the general aim of the course could be about teaching with formative assessment. The course assignment can be limited to a domain: embedded assessment techniques for fast feedback (depth first), even limited to a topic: force diagrams (depth first again), and the assignment involves one theory-practice
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7.3.2 Mastering ICT skills: process, problems, and solutions

In this section, we describe our understanding about how participants learn ICT skills, their problems on the way, and possible solutions. In the ICT in IBSE course, participants make use of the Coach introductory and tutorial activities for practicing manipulation skills with the ICT tools. During the practice with Coach, they first meet initial hurdles of learning a new tool (how-to problems). In this situation, direct support from the course instructor and/or peers is needed. We learnt from the Dutch case that collective practice with the ICT tools in small groups of two or three gives faster progress than individual practice at home. Moreover, such collective practice in small groups is more effective than the practice under the plenary step-by-step instructions to the whole class of 10 to 20 participants (the Slovak case).

When modifying or developing the Coach activity for the ICT in IBSE lesson or interpreting the resulting data, participants might encounter TCK problems. TCK problems entail: a) advanced features and facts of the ICT tool; b) understanding of the phenomenon to be experimented with or modelled with the ICT tool; c) general experimentation/modelling skills; and d) knowledge of the mental model behind the digital tool. Participants can get over their TCK problems if sufficient contact time is scheduled for them to troubleshoot the problems in consultation with the course instructor and peers.

The expert level of using the ICT tool comprises one’s ability to troubleshoot the TCK problems independently. Across the three cases, most participants reached a sufficient user level of handling the ICT tools but not this expert troubleshooting level. Obviously, troubleshooting a TCK problem is not a straightforward process. It requires participants to understand the mental model describing the way the ICT system works. Moreover, it demands their confidence and commitment in searching and trying out solutions. The computer performance test, used in the Slovak and Vietnamese courses, can reveal participants’ lack of troubleshooting skills, and so it can make participants aware of what they have to think about while facing problems with their Coach activities. Through trying to solve test problems with a reasonable level of complexity and discussing solutions with the course instructor afterwards, participants might become more confident and experienced in troubleshooting TCK problems. Such awareness and confidence of participants together with their sufficient manipulation skills are a basis to develop their troubleshooting skills further through preparing experimentation/modelling activities and teaching with the ICT tool after the course.

7.3.3 Inquiry teaching with ICT in different education cultures

Considering the issue of teacher learning to teach by inquiry, we prepared and expected our course participants to get first experience with inquiry teaching with ICT. The theory-practice cycle was valuable to make them more aware of what IBSE involves, of what are differences between guided versus open inquiry, and of how to involve pupils in planning and interpretation of an experiment. However, the research findings across the three case
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studies clearly show that participants with theoretical knowledge of IBSE still need much help to translate their knowledge and inquiry intentions into concrete lesson designs. Furthermore, one theory-practice cycle is not enough to make participants with little IBSE experience to become skilled at IBSE implementation. The analysis of the lesson plans and classroom try-outs showed considerable inconsistency between inquiry objectives and activity specifications and noticeable deviations between intended and actual IBSE lessons. These are persistent problems, which have been discussed in the literature on IBSE and laboratory teaching for a long time (e.g. Abrahams & Millar, 2008; Germann et al., 1996; Hofstein & Lunetta, 2004; Tamir & Lunetta, 1981). This means that the ICT in IBSE course under the time constraints did not push its participants far enough yet in the direction of inquiry teaching with ICT. Obviously, participants’ achievement through the course is just a good point of departure; more theory-practice cycles are needed to bring them further to effective implementation of ICT in IBSE in teaching practice.

An IBSE lesson pattern is influenced by the educational system as we see many links between our data and characteristics of the local educational system (Table 7.1). We compare the ICT in IBSE lesson plans of the Dutch and Vietnamese participants and elaborate this point further. The differences and links to the educational system show in several aspects. First, most Vietnamese participants chose a topic and context limited to the curriculum and mainly verification activities, whereas their try-outs were outside regular lessons with small pupil groups. In contrast, most Dutch participants were more adventurous in selecting topics outside the formal syllabus, whereas their try-outs were in regular lessons. This difference in choices of topics and contexts for the ICT in IBSE lessons reflects what participants are used to in their educational systems: the Vietnamese participants are often relying much on curriculum and syllabus, whereas the Dutch participants have the freedom to deviate from the textbook, and choosing contexts close to real-life situations is stimulated in Dutch schools.

Second, most Vietnamese participants intended to take control over the entire classroom activity through the guided-discovery lesson pattern, whereas for half of the Dutch ICT in IBSE lesson plans, pupils were provided with more participation and independence in more-open inquiry patterns (Figure 7.4). This difference in the level of guidance and control in the classroom links to the cultural system, which is operationalised in the educational system in each country. The Vietnamese participants are used to preparing everything for pupils and tell pupils what to do, so they might not see and trust what pupils can do in a more-open situation. This way, Vietnamese teacher-centred education is mismatched with the pupil-centeredness required in open investigations. In contrast, Dutch culture is egalitarian. That creates problems in classroom management for the Dutch participants as student teachers but matches with requirements for higher levels of inquiry.

Third but not least, the Vietnamese participants focussed more on pupils’ manipulations of equipment and software in the “execution of experiment/model” phase, whereas the Dutch participants emphasised pupils’ manipulations of ideas sufficiently in the “conception, planning and design” phase and the “analysis and interpretation” phase of the ICT in IBSE lesson (Figure 7.5). This difference in focus of the ICT in IBSE lesson might relate to IBSE perception and experience of Vietnamese versus Dutch participants. In spite of studying IBSE theory, Vietnamese participants showed a narrow interpretation of IBSE,
which is considerably different from the common perception of science educators. The main reason may be that they never experienced open investigation themselves (as a learner and as a teacher). The Dutch participants had personal experience with independent research or even with open investigations in their Bachelor and Master studies. To conclude, the education culture influences teachers’ perception and implementation of inquiry-based teaching with ICT. This results in different typical patterns of ICT in IBSE teaching in different countries.

<table>
<thead>
<tr>
<th>Operationalised inquiry opportunities for pupils</th>
<th>Percentage of lesson plans</th>
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<tbody>
<tr>
<td>1.1</td>
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</tr>
<tr>
<td>1.2</td>
<td>20</td>
</tr>
<tr>
<td>1.3a</td>
<td>40</td>
</tr>
<tr>
<td>1.3b</td>
<td>60</td>
</tr>
<tr>
<td>1.4</td>
<td>80</td>
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<tr>
<td>1.5</td>
<td>100</td>
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<td>2.1</td>
<td>20</td>
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<td>2.2</td>
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The list of categories of inquiry skills within the first three phases of an ICT in IBSE activity:

1. Conception, planning and design
   1.1 formulates a question
   1.2 formulates an hypothesis or expectation
   1.3a defines variables of experiment/model
   1.3b defines how each variable will be measured or modelled
   1.3c defines procedures to analyse experimentation/modelling data
   1.4 predicts results of experiment/model based on its design

2. Execution of experiment/model
   2.1 manipulates software and/or apparatus
   2.2 measures/determines values of variables
   2.3 records experimentation/modelling data
   2.4 decides/explains experimentation/modelling techniques
   2.5 works according to the own design

3. Analysis and interpretation
   3.1 chooses representations of data
   3.2 determines accuracy and precision of data
   3.3 determines relationships
   3.4 compares the results to the hypothesis/prediction
   3.5 explains experiment/modelling results
   3.6 discusses limitations of the experiment/model
   3.7 proposes generalizations of the results

Figure 7.5. Percentage of Dutch lesson plans (N=30) and Vietnamese lesson plans (N=22) in which each inquiry component was operationalised as a learning opportunity (not a prescriptive recipe) for pupils.

The choices, which the Vietnamese participants made regarding their ICT in IBSE lessons, were not necessarily bad choices considering their experience and teaching conditions. However, Vietnamese pupils should be more involved in the planning and interpretation phases of the ICT in IBSE activity. The Vietnamese participants should not only develop the skill of designing and implementing ICT in IBSE activities that are effective
in current classroom conditions but also change their perceptions of what IBSE means. To change such perceptions, a solution is letting Vietnamese participants experience open investigation activities with or without ICT earlier in their studies. There are many open investigation activities in teacher journals and in international lesson materials, which can be adapted to use in Vietnamese classrooms and which have been used in other countries of South East Asia.

Inquiry involves learning about and using methods for generating and validating knowledge. Our research focused on learning inquiry skills as one of the objectives of a physics/chemistry lesson. The integration of inquiry as learning objective in school curricula is a general trend of educational innovation worldwide. However, we realize that many national examinations and entrance tests for universities, in Slovakia and Vietnam for example, do not yet measure this inquiry goal. Consequently, a lesson with an inquiry goal may not be relevant yet for pupils and teachers in such countries. As long as examinations are the way they are now, little class time will be scheduled for this. On the other hand, inquiry can also be used as a teaching method to teach concepts rather than inquiry skills. To support concept development, the approach should be much more "guided" (Kirschner et al., 2006), and demonstrations are even often more effective than laboratory activities (Garrett & Roberts, 1982; Millar, 2010). In laboratory/ICT activities, pupils are distracted by many things that may not be relevant for concept learning. In a laboratory demonstration, attention is much more focussed on the key concepts. Therefore, whether you should use open or guided inquiry depends on your goal. If conceptual understanding is aimed at, then guided inquiry should be applied. If inquiry skills and reasoning with evidence are aimed at, then you should go for open inquiry. With curricula in Slovakia and Vietnam and with the university-entrance test that they have, guided inquiry is more effective for that. This clear-cut differentiation between using IBSE for teaching inquiry goals and using IBSE as a teaching method for conceptual goals has to be explained explicitly to teachers in countries like Vietnam, where inquiry as a legitimate science-education goal is still rarely implemented.

7.4 Reflection on the methods

7.4.1 Design research approach

The literature shows many ideas about how design research can take place but also claims that the way to conduct a concrete design research project should be based on the design requirements and context (van den Akker et al., 2006). What is special in the design we had to make? What did that mean for our design research? We started this research and design project with the unique objectives of the course to be developed and a clear view about design criteria. First, we intended to develop a time-effective teacher-education course on ICT in IBSE teaching, which is intensive, innovative, but challenging. Second, the course was aimed at explicit short-term objectives regarding knowledge and skill achievement: ICT mastery and ability to design, teach, and self-evaluate an ICT in IBSE lesson. Furthermore, we intended the course to have an ambitious long-term effect: confidence and motivation of participants to continue studying and applying ICT in IBSE independently. Third, we saw that many countries have the same concern of how to prepare and support teachers to incorporate ICT in IBSE effectively. Consequently, the course to be developed had to be flexible enough
to be applied in different educational and cultural contexts in different countries with different teacher groups, which have diverse backgrounds and lack ICT/IBSE teaching experience. Therefore, we chose the design research approach for developing and evaluating an effective, flexible, short ICT in IBSE course. This approach worked well for our aims and in our research environment.

At the beginning of this design research, there was not a complete design of the course that we aimed to develop, but we had something at hand: the four pedagogical principles, which were defined from the literature on different related fields such as teacher PD, TPCK, IBSE, ICT in science education, and design research. We started the design research with these pedagogical principles and concluded it with these principles as the core of the basic design of the ICT in IBSE course. The principles guide the thinking of the design researcher about what to keep and what to change as far as adaptation and optimisation of the course are concerned. Interestingly, a small number of course objectives and pedagogical principles can help to decide which of the 100+ variables to operationalise and implement; what to evaluate; and how to communicate about the research. Furthermore, these principles can be considered as independent, validated educational products, which teacher educators can “buy into” and use for broader aims than only ICT in IBSE integration. The experience and outcomes of this design research confirm the essential roles of pedagogical principles in design research: establishing the theoretical model; giving guidelines and structure to the (re)design, implementation, evaluation, and optimisation process; and helping to communicate the design research to others.

Robustness of a design product is a concern for design research: newly developed innovative products might not be applicable to routine conditions outside of research settings. For example, some developers aim to innovate something in the school curriculum, and so they intend to try out their innovative ideas, methods, or materials with schoolteachers and pupils. However, they realise that there are many disturbing factors in the school context, so they decide to take out their innovations out of the regular classroom, and test them with pupils in a better-controlled setting (e.g. the researchers teach and coordinate their innovative course themselves). Consequently, it will be difficult to transfer their innovative products to other teachers. In our design research, we collaborated with local teacher educators in every step of the design process from elaborating and adapting the course scenario to analysing the effectiveness of the course. In the Dutch case, the researcher played the coordinator role. The robustness test of the Dutch course in the fourth cycle showed that such coordinator role was safely transferred to the local teacher educator (see Chapter 4, Section 4.4). In the Vietnamese case, the researcher played part of the teaching role, but the Vietnamese course after the research project without any involvement of the researcher still showed up its effects. The two cycles of the Slovak course were already in routine implementation conditions without the direct participation of the researcher. The three country versions of the ICT in IBSE course have been institutionalised and incorporated in the regular programmes and systems, where these versions were tried out. To conclude, we incorporated the robustness test, cooperated with the local instructor in our design research, and achieved successful outcomes. Therefore, we strongly recommend a robustness-test step and extensive cooperation between the design researcher and the local instructor in design research.
Chapter 7

It is common that one conducts design research in a specific context (e.g. one school, one teacher, one class) with a number of cycles and ends up with an educational product and some ideas about strength and weakness of this product. This helps to understand the learning process and problems of participants, but it is not easy to claim the design product applicable in broader contexts. In our design research, we also went “depth first” with three iterative cycles in the Netherlands and arrived at an optimal product. However, we went one-step further than this. We did “breadth later” by implementing and evaluating the course as an educational product in other situations (Slovakia and Vietnam) and considered this as a strong test of the generalizability of the pedagogical principles and of the transferability of the basic course design with the support materials. To conduct a thorough and convincing test of the generalizability and transferability, we took contexts that were extremely different, not only in educational and cultural systems, but also in teacher education models (i.e. pre-service, in-service, and something in between). Our research findings confirm that it is possible to test an educational product in extremely diverse contexts, and it is worthwhile since we can obtain a clear picture of which components of the educational product are most important, which components should remain the same, and which components can be tuned to the local context. Our research outcomes also imply that it is possible to have an international design of a course or other educational design product (incl. materials, scenarios, and guidelines) and apply it in different educational systems. It is possible to make sustainable and effective innovation that can be applied broadly and internationally. The adapting and fine-tuning can be done in case studies as we did. The approach that we took was more efficient than redeveloping the course in each context from scratch. After all, we would like to recommend a generalizability and transferability testing as part of design research.

7.4.2 Measurement methods and instruments

This present research used multiple instruments for data collection and analysis. With these instruments, data were collected from a variety of sources and by different data collectors (i.e. the researcher, the course instructor, course participants). This way, we did record both intended and unintended outcomes while the course was implemented. Most outcomes were evaluated by more than one instrument thus allowing for data triangulation. In particular, to evaluate ICT mastery of participants, we collected data through their self-confidence report, direct observations of ICT manipulations in live sessions and classroom try-outs, their Coach activity for the ICT in IBSE lesson, and the computer performance test. Each type of data reflects different ICT-mastery aspects, which should be aligned with each other. Self-confidence data predict how likely the participants is able to operate the tool and reflect their motivation in using the tool. Direct observations of ICT manipulations provide impression of their own ICT skills: whether they can handle the software fluently and independently. The Coach activity is an illustration of what they can accomplish with their ICT mastery, and it is close to what we expect them to make and use in their class. Data from the computer performance test are the most convincing, because the test puts participants in the situation where they have to use all of their ICT mastery to solve TCK problems. The test data confirm participants’ manipulation skills and troubleshooting skills. Moreover, the test can be used as a learning tool, which makes the participants aware of TCK problems and
troubleshooting approaches. Consequently, the computer performance test can be used for both formative and summative assessment purposes.

In the present research, the inquiry-analysis inventory was used to analyse ICT in IBSE lesson plans and actual lessons. It categorises the level of guidance in ICT in IBSE activities and then every intended action of pupils (inquiry opportunity) is coded into one of 22 inquiry-skill categories. This produces a profile of which inquiry skills are being called upon and exercised during the activity. With this instrument, we analysed which opportunities for exercising inquiry skills were included in lesson plans and which skills were actually used in their lessons (through observation). Moreover, the inquiry-analysis inventory helps to make participants more aware of which objectives are, of which objectives are not operationalised in their lesson plans, and of which inquiry opportunities are not actually realised in their lessons. It is valuable by making shortcomings visible and by proposing simple changes in the ICT in IBSE activities, which produce large changes in the level of inquiry. To conclude, we recommend broader use of data-triangulation methods, the computer performance test, and the inquiry-analysis inventory than the context of the ICT in IBSE course.

7.4.3 Limitations of the research and suggestions for future research

This present research has certain limitations that should be taken into consideration. First, both spoken and written forms of the research data were in four languages: English, Dutch, Slovak, and Vietnamese, whereas the researcher masters only Vietnamese (first language) and English (second language). Consequently, analysis of the data in Dutch and Slovak was based on the voluntary cooperation with the local course instructors, and quality of the data analysis outcomes was partly dependent upon the work of these instructors. Because the local instructors could not spend much time for data analysis, much classroom video data were not used, although these data would possibly reveal extra and relevant issues about participants’ ICT in IBSE implementation. If the present research had been at a larger scale than an independent PhD project, then there should have been additional researchers from the Netherlands and Slovakia involved.

Second, both learning scenario and instructional materials contribute to learning outcomes of learners, so much design research concentrates on improving these two components of an instructional design. In this present research, we focussed more on optimising and adapting the course scenario than on the support materials. The support materials were necessary for the sufficient implementation of the pedagogical principles and the satisfactory attainment of the course objectives. Already in the first cycle of the course, the participants very much appreciated the usefulness of the materials we applied. These materials were based on the available materials from CMA and from previous projects (Chapter 3, Section 3.1.4). However, when evaluating summative effects of the course, we were aware of the needs to revise and enrich the existing materials (e.g. the lesson-plan form, the Coach exemplary materials) and develop new materials (e.g. a repository of the most common TCK problems and related solutions) as far as participants’ learning process and their problems are concerned. If this awareness had come up earlier, effectiveness of the course should have been higher. Therefore, we suggest for future design research on development of a new teacher education course that the design researcher should place more emphasis on participants’ learning process and search for their learning problems right in the
first cycle. Next, it is necessary to evaluate critically which problems result from the course scenario (leading to refinement of the scenario) and which problems can be reduced by improving the support materials.

Third, after one theory-practice cycle with the ICT in IBSE try-out, participants gain new understandings and skills, which are learning outcomes of the course, but just partly measured through their self-reports via the assignment report, the live presentation in the last session, and the post-course questionnaire. If the course had been extended for the second ICT in IBSE try-out, we could have had a more complete evaluation of the ICT in IBSE objective. Furthermore, the best test of an educational product developed through design research might be to measure its impact on pupil learning. Within the present research, we focussed on measuring participants’ knowledge, skills, and motivation gained through the course. In the observation of their ICT in IBSE try-outs, we focussed on their teaching, and pupils’ learning process and results were used formatively as part of the feedback on an implemented lesson plan. Although we collected evidence about whether the participants used their new ICT/IBSE knowledge and skills after the course in their lessons, the data to analyse quality of such follow-up use (e.g. lesson plans, classroom observations) were not collected. Therefore, we strongly recommend a follow-up research that collects data from second or third ICT in IBSE try-outs of the course participants and that focuses on both the teaching of the teacher and the learning outcomes of pupils. With this follow-up research, we might be able to arrive at a more complete conclusion about effectiveness of the ICT in IBSE course.

7.5 Epilogue

Based on our positive experiences with one theory-practice cycle, we think that this principle should be wider applied in teacher education. Would it be possible to identify a small number of core practices and have student teachers go through one theory-practice cycle for each? It is common practice that each teacher education programme invents its own wheels. In the present research, we designed an educational product, and using pedagogical principles, we were able to fine-tune it to rather different boundary conditions in different programmes and educational systems. Our experience suggests that with careful design and well-chosen pedagogical principles, courses and other educational products could be fine-tuned and shared. Therefore, it is possible to have more-productive standardisation among teacher education courses.
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To access these appendices, please use the following download link:
https://drive.google.com/folderview?id=0B3As3Mv4Uy4uM0VXZDNic1p6LTg&usp=sharing
Summary

Background and research questions

Information and Communication Technology (ICT) and Inquiry-Based Science Education (IBSE) with innovative features have been available for more than thirty years and have been included in formal science curriculum documents. The science education community mostly agrees about relevance of integration of ICT in IBSE for pupils exercising inquiry practices, acquiring inquiry skills, and understanding scientific inquiry. However, ICT in IBSE is still very much under-used and applied at a relatively small scale in most countries. When it is used, the use often lacks the basic characteristics of inquiry. Factors involved are amongst others: a) limited curriculum time and limited teacher preparation time; b) mismatches of the IBSE goals with commonly used lesson materials; teaching methods; and assessment and examination (e.g. prescriptive nature of materials and methods, predominance of content over inquiry goals), and c) insufficient teacher preparation and training on integrating ICT into IBSE. All of these factors need to be changed consistently and in concert to realise proper incorporation of ICT and IBSE into a classroom where manipulation of equipment and software is turned to manipulation of ideas and concepts for knowledge generation and validation.

Within our PhD project, we focussed on preparation and training of science teachers on ICT in IBSE teaching and developed an effective and relatively short course for student teachers and teachers with diverse teaching experience. The present research confined the ICT in IBSE teaching to a) three constructional tools: data logging with sensors, video measurement, and dynamical modelling and b) the use of these tools to support inquiry by pupils. In an ICT in IBSE activity, the pupils should have some role not only in executing the experiment/model but also to some extent in formulating research questions, designing the experiment/model, and interpreting the results. We developed a short course so that it can be accommodated within typical overloaded teacher education programmes or adopted as an in-service course. Furthermore, educational theories and products, such as our ICT in IBSE course, do not always travel well as educational and cultural contexts in different schools and countries can be very different. That is why the present research included three case studies in The Netherlands, Slovakia, and Vietnam and in pre- and in-service teacher education. That way we could test the transferability of our course design and the generalizability of the pedagogical principles at the basis of this design.

The aim of the present research was twofold. First, the objective was to design a short course, which – with some adaptations - will be effective in widely different educational settings. Second, this research was to investigate the validity of pedagogical principles, which were used to guide a) the design, implementation, evaluation, and optimisation of the course and b) the extent to which the course can be adjusted to the different settings in the Netherlands, Slovakia, and Vietnam. The pedagogical principles are at a higher level of abstraction and intended to be generalizable across educational and cultural contexts. The design research approach was applied as it can provide guidelines and scientific reasoning for such a research and design process, which was guided by the two research questions. First, what are characteristics of an effective, short course for Dutch student teachers to learn to
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apply the ICT tools in IBSE? Second, to what extent is the course applicable in different educational and cultural contexts of pre- and in-service teacher education in different countries (i.e. the Netherlands, Slovakia, and Vietnam)?

Course design and research design

The general aim of the course was elaborated into the four objectives as follows:

1. **Awareness objective**: participants become aware of educational benefits of the ICT tools in science education.
2. **ICT mastery objective**: participants master skills to operate the ICT tool.
3. **ICT in IBSE objective**: participants can design, implement, and evaluate an ICT in IBSE lesson.
4. **Motivation objective**: participants are motivated to continue studying the ICT tools and trying out ICT in IBSE lessons with pupils.

The ICT in IBSE objective (3) was considered as the *main objective of the course*. In order to reach this objective, participants had to achieve a certain minimum level of mastery of the ICT tools (2). The awareness objective (1) and motivation objective (4) were aimed at the course’s long-term effects on participants’ teaching practice. The Coach platform for data logging, video measurement, and modelling was used together with available support materials (i.e. Coach introductory, tutorial, and exemplary activities) and materials that we developed (i.e. forms for designing and self-evaluating the ICT in IBSE lesson).

The literature on design research and on professional development of teachers led us to the following pedagogical principles (see Chapter 2) as the basis for (re)designing, evaluating, and optimising the ICT in IBSE course:

1. **One theory-practice cycle**: participants are required to go through at least one complete cycle of designing, implementing, and evaluating an ICT in IBSE lesson within the course. Participants will apply the IBSE theory in a design for an ICT in IBSE lesson, which they will also try out in the classroom, self-evaluate, and report in the final session of the course.
2. **Distributed learning**: participants study in live sessions and carry out individual assignments in between the sessions with the support materials and in consultation with the course instructor. Learning time is distributed between live sessions and individual assignments, but is also carefully distributed over a longer period to provide opportunities for a well-planned try-out in a real classroom.
3. **Depth first**: participants are introduced to the possibilities of the three tools after which they specialise in only one ICT tool. Learning time is prioritised for an in-depth study and application of one tool (one-tool specialisation) rather than broad study of all three tools at a more superficial level, so depth first - breadth later.
4. **Ownership of learning**: participants have freedom to select what to learn and how to learn it, using the course scenario and support materials in order to achieve the course objectives. The individual participants pursue their self-tailored learning process in which they make their own choices regarding the tool, the grade level, topic, and activity for their ICT in IBSE try-out with pupils.

The four objectives, four pedagogical principles, and support materials together form the general design of the ICT in IBSE course.
To examine the effectiveness of the ICT in IBSE course; validity and generalizability of the pedagogical principle; and transferability of the course design in different education contexts, we conducted the Dutch, Slovak, and Vietnamese case studies. These three case studies were related; the Dutch case study was the earliest and most extensive, followed by the Slovak case study, and then the Vietnamese case study. All three case studies a) concerned the same questions about implementation of the pedagogical principles and course design, usefulness of the support materials, and attainment of the course objectives, b) applied the same evaluation framework, and c) used the same instruments for data collection and analysis.

The course evaluation was guided by two main questions:

A. To what extent were the four pedagogical principles implemented as intended?
B. To what extent did the ICT in IBSE course achieve its four objectives?

Question B involves the evaluation of the effects of the course on participants, which resulted from actual implementation of the pedagogical principles, the course design, and the support materials. The evaluation of this actual implementation was guided by Question A and based on a comparison between a) the intended course programme and b) the actual activities of participants during the course. To evaluate attainment of the course objectives, we first operationalised performance levels for each objective. The definition of these levels was based on theoretical considerations and aligned with time-constraint conditions of the course.

After that, we collected data, compared the data-analysis outcomes with the pre-defined levels of the course objectives, and concluded which level(s) of each objective the participants achieved. Chapter 3 presents this evaluation framework in detail with related instruments for data collection and analysis (i.e. pre-course, post-course, and follow-up questionnaires; observations and video recording of live sessions and classroom try-outs; participants’ ICT in IBSE lesson plans and self-evaluation reports of the classroom try-outs; computer performance test for each tool; the inquiry-analysis inventory; and the communication records). With these instruments, data were collected from a variety of sources and by different data collectors (i.e. the researcher, the course instructor, course participants).

Accordingly, we could record both intended and possibly unintended outcomes as the course was implemented. Most outcomes were evaluated by more than one instrument thus allowing for data triangulation.

In the Dutch case study, we further operationalised the pedagogical principles in the initial scenario of the ICT in IBSE course. With “scenario”, we mean the programme of the course and all instructor and participant activities and assignments (see Chapter 3). After that, we implemented and evaluated the course with 40 physics/chemistry student teachers spread over four sequential cycles. Among these four cycles, Cycles 1 and 2 were for fine-tuning of the course scenario. The course evaluation (Questions A and B) and experiences with the course in Cycle 1 (incl. what did work, what did not work, and why) suggested revisions of the initial scenario. These revisions were aimed at more faithful implementation of the course in Cycle 2 and with respect to many factors such as diversity of participants’ background and ability; school schedules; and curriculum time for ICT in IBSE try-outs. Likewise, the Cycle 2 evaluation was guided by the objectives and pedagogical principles and resulted in further optimisation of the course scenario. We achieved the faithful implementation of the four principles in Cycle 3. Consequently, in this cycle, the summative effects of the Dutch version of the ICT in IBSE course were evaluated, and only minor suggestions were made for further
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The robustness of the course design and the ecological validity of the pedagogical principles were tested in Cycle 4 under routine implementation conditions without the extra support of the researcher.

The new understanding of how the course was developed and why it was effective (Dutch context) together with the basic course design (incl. course objectives, pedagogical principles, and support materials) enabled the tailoring of local versions of the ICT in IBSE course in different contexts. The ICT in IBSE course was adapted and tested in a) two cycles with 66 physics/biology/chemistry teachers with diverse teaching experience (1 to 33 years of teaching) in Slovakia (see Chapter 5). The two cycles of the Slovak course were already in routine implementation conditions without the direct participation of the researcher. The ICT in IBSE course was adapted and tested in one cycle in Vietnam with 22 master students in physics education, who either had taught for 2 to 9 years or came straight from a Bachelor teacher-education programme (see Chapter 6). Evaluations of the three local versions of the course enabled us to draw conclusions about a) the extent to which the four objectives can be attained, b) the validity and generalizability of pedagogical principles, c) the transferability of the course design, and d) the practical relevance of the course. These evaluations led us to new understanding of the extent to which the pedagogical principles can guide the fine-tuning of the basic design of the ICT in IBSE course to varying boundary conditions (see Chapter 7).

Findings, discussion, and conclusions

Chapter 4 presents the Dutch case study, which resulted in an improved and successful course scenario in which the Dutch participants achieved the course objectives also when the course was taught under routine conditions (Cycle 4). The iterative evaluation and refinements of the Dutch course confirmed the validity of the pedagogical principles in the Dutch context. The support materials proved necessary and useful for the sufficient implementation of the pedagogical principles and the satisfactory attainment of the course objectives. To conclude, the four course objectives, the four pedagogical principles, and the optimised scenario with the support materials establish the core characteristics and basic design of an effective short ICT in IBSE course for Dutch student teachers. Findings from the iterative refinement of the course show that fine-tuning the distribution of time and individual assignments is crucial as far as distributed learning is concerned. Direct, personalised support (in live meetings and/or via emails) and sense of direction (via explicit support framework plus assignment tracking and stimulation) are crucial factors to ensure effectiveness of independent learning, especially the quality of the ICT in IBSE lesson plan. These factors create a balance between much freedom of choice and appropriate guidance, which is essential to establish ownership of learning.

The Dutch, Slovak, and Vietnamese contexts for the ICT in IBSE course were different in many aspects (e.g. scheduling requirements, school conditions, and characteristics of participants). First, the Dutch course was limited to 12 contact hours out of 28 hours of total study time, but it was spread over 11 weeks. The Vietnamese course was compressed in 5 weeks, but 30 hours out of total 60 study hours were scheduled for live activities. The Slovak case had the least constraints, regarding both contact hours (25 out of total 40 study hours) and “spread” of the course (15 weeks). Second, the Dutch school conditions (e.g. curriculum time, teacher preparation time, national examinations, pupils’ experience with ICT...
and IBSE, availability of equipment and software) were not excellent but sufficient. Meanwhile, the Slovak school conditions were insufficient, and the Vietnamese conditions were very poor. Third, the Vietnamese and Slovak participants were experienced teachers, but their ICT mastery entrance level was low. The Dutch participants had more experience with the ICT tools and felt more free to decide their own lesson objectives and teaching methods. However, they lacked teaching experience, especially classroom management skills. Vietnamese teachers work in an education system with a strong hierarchical culture and much less autonomy than in the Dutch system. Lessons are teacher-centred and there is no tradition of open learner investigations in secondary school and teacher education. All three groups of participants lacked practical experience with inquiry teaching with or without ICT, so ICT in IBSE teaching was challenging for them. For all three versions of the course, diversity of participants and time constraints were challenging contextual factors.

Across the three case studies (Chapters 4, 5, and 6), the awareness and motivation objectives of the ICT in IBSE course were achieved as expected. The participants could enumerate relevant benefits of the ICT tools. They devised plans and actually continued studying the ICT tools and teaching ICT in IBSE lessons after the course. About the ICT-mastery objective, all three groups of participants were able to operate the Coach tool fluently after the course. Compared with the Dutch participants, the Vietnamese participants attained a higher mastery level for the chosen tool, and the Slovak participants achieved a similar ICT mastery but with all three ICT tools. This shows effectiveness of the many more contact hours with direct, personalised support scheduled for the ICT-mastery objective to compensate for the low ICT entrance of the Slovak and Vietnamese participants.

About the ICT in IBSE objective, all three groups of participants were able to design and realise acceptable ICT in IBSE lessons considering their teaching conditions and their inexperience with inquiry teaching with ICT. The Dutch participants could design and realise better ICT in IBSE lessons than the Slovak and Vietnamese participants. Many Dutch participants were able to engage pupils in designing experiments or models and predicting and interpreting results as expected. Meanwhile, the Slovak and Vietnamese participants focused too much on pupils’ execution of experiments or models (manipulation of equipment and software) and did not sufficiently involve pupils in moving back and forth between the physical and theoretical worlds (manipulation of ideas and concepts). Most Slovak and Vietnamese participants intended to take control over the entire classroom activity through plenary systematic explanations and/or prescriptive worksheets for the group work. In contrast, in half of the Dutch ICT in IBSE lesson plans, pupils were required to take a larger role in conception, planning, and interpretation of the experiment/model in more-open inquiry patterns. This shows a clear difference in teacher/pupil centeredness and education culture among the three countries.

Although familiar with theory of IBSE, all three groups of participants had trouble to operationalise real inquiry in lesson plans and even more so in the classroom. There were many deviations between intended and actual ICT in IBSE lessons, and these resulted from reasons such as shortcut of intended inquiry opportunities; tasks that were too demanding; over ambitious timing; and ineffective communication with pupils. However, Dutch, Slovak, and Vietnamese participants were able to identify the shortcomings in their ICT in IBSE
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lessons and suggest relevant revisions of their lesson plans for future use. To conclude, the basic design of the ICT in IBSE course was effective, practical, and transferable in the different educational and cultural contexts of pre- and in-service teacher education in different countries. The course can cater to diverse groups of teachers and teacher-education programmes, and it fits into time-constraint conditions. For all three cases, the ICT in IBSE course achieved its objectives to the pre-determined acceptable level, except that for the ICT in IBSE part there was still much room for improvement.

Considering the issue of teachers learning to teach by inquiry, we prepared and expected our course participants to get their first experience with inquiry teaching with ICT. The theory-practice cycle was valuable to make them more aware of what IBSE involves, of what are differences between guided versus open inquiry, and of how to involve pupils in planning and interpretation of an experiment. It was concluded that the educational and cultural system influences teachers’ perception and implementation of inquiry-based teaching with ICT. This results in different typical patterns of ICT in IBSE in different countries. The analysis of the lesson plans and classroom try-outs using the inquiry-analysis inventory revealed considerable inconsistency between inquiry objectives and activity specifications and noticeable deviations between intended and actual IBSE lessons. These are persistent problems, which have been reported worldwide (Abrahams & Millar, 2008; Abrahams & Reiss, 2012; Tamir & Lunetta, 1981). Many teachers do have problems to operationalise inquiry in the classroom, even in countries like The UK and The U.S. where inquiry has been emphasized in the curriculum for a long time. Research findings from the Vietnamese case study shed light on challenges of and potential solutions to the application of IBSE in a hierarchical education culture (Chapter 6). Obviously, the ICT in IBSE course under the time constraints does not push its participants far enough yet in the direction of inquiry teaching with ICT. Participants’ achievement through the course is a starting point; more theory-practice cycles are needed to bring them further in such ICT in IBSE direction.

In the present research, the pedagogical principles are valid in providing not only the framework for implementing, evaluating, and optimising the course in a specific context but also guidelines for effective adaptation of the course to varying boundary conditions. When adapting the course to a different context, the “one theory-practice cycle” principle should not be changed. Instead, the “depth first” and “distributed learning” principles can be adjusted by the course instructor to some extent to the specific context, considering the entrance level and other characteristics of the participants and the scheduling requirements. The “ownership of learning” principle has to be enabled to provide a dial for participants to self-tune the course to their own interest and ability. The adjustment with distributed learning and depth-first makes the first flexible phase: ICT mastery, which can be lengthened (Slovak case) and compressed (Vietnamese case) in order to compensate for the low ICT entrance, accommodate diversity of the participants, and align their activities, assignments, and efforts with the intended attainment of the ICT mastery objective. Such ICT mastery attainment is necessary for the participants to be able a) to design and teach the ICT in IBSE lesson and b) to continue studying and using the ICT tools after the course. Among the four course objectives, the ICT-mastery objective can be achieved in a compressed course with sufficient contact hours, whereas the learning with respect to the ICT in IBSE objective needs to be distributed sufficiently to allow for a well-planned and mature lesson plan and curriculum
time for classroom try-out. The support materials proved necessary, useful, and robust in different contexts. This finding suggests that it is not always necessary to develop materials locally to have effective educational innovations. Instead, with certain adaptations, one can use existing materials.

**Reflections on the findings and methods**

Based on our positive experiences with one theory-practice cycle, we think that this principle should be wider applied in teacher education. Would it be possible to identify a small number of core practices and have student teachers go through one theory-practice cycle for each? For example, the study of formative assessment could be followed by classroom practice with embedded formative assessment and feedback. Regarding the depth-first principle, deeper understanding of one ICT tool has surplus value compared to partial understanding of all three tools, and it leads to better transfer to the whole ICT environment (breadth-later). This further suggests the application of the depth-first principle as part of a solution for content overload in teacher-education programmes. Regarding the learning of ICT skills, collective practice of ICT skills in small groups is more effective than either individual practice at home or the practice under plenary step-by-step instructions to the whole class. Personalised, direct support from the course instructor and peers is essential for participants to get over initial hurdles of learning a new tool and to troubleshoot TCK problems. To troubleshoot TCK problems independently, participants need to understand how the ICT system works and to be confident and committed in searching and trying out solutions. Taking the computer performance test can be a first step to learn such troubleshooting skills.

At the beginning of the present research, we defined the unique objectives of the course to be developed and a clear view about design criteria. Based on these objectives and criteria, we chose the design research approach to develop, evaluate, and optimise the course as an educational product through research, and this approach worked well. We started this research and design project with the pedagogical principles and concluded it with these principles as the core of the basic design of the ICT in IBSE course. These principles can be considered as independent, validated educational products, which teacher educators can “buy into” and use for broader aims than only ICT in IBSE integration. Pedagogical principles establish the theoretical model underlying the course design, provide guidelines and structure to the (re)design, implementation, evaluation, and optimisation process, and help to communicate the design research to others. The role of pedagogical principles in design research is indeed essential. Moreover, in our design research, we incorporated a) a “robustness test” step to try out the course under routine conditions and b) a “generalizability and transferability testing” step to try out the course in different programmes or even countries. We achieved successful outcomes with these steps. Consequently, we strongly recommend robustness and generalizability/transferability tests as part of design research.

Main limitations of the present research were that it only measured the quality of one theory-practice cycle, that it did not have an opportunity to measure the further development of participants in later ICT in IBSE activities in their classrooms, and that it did not measure pupil results. Learning to teach the IBSE way takes a longer trajectory than this course, and so our measurements only show the start of the participants’ development. For the same reason,
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there was no point in measuring pupil achievement, as improvement of their inquiry skills would only become visible after a series of lessons rather than one lesson.

It is common practice that each teacher education programme invents its own wheels. Our research outcomes through the development/adaptation, implementation, and evaluation of the ICT in IBSE course in the Netherlands, Slovakia, and Vietnam indicate that with careful design and well-chosen pedagogical principles, courses and other educational products could be fine-tuned and shared. The fourth and fifth Dutch course and the second Vietnamese course were implemented by the local course instructors without any involvement of the researcher. The third Slovak course is planned within a new large-scale national project, which is aimed at implementation of ICT tools across science subjects in Slovakia. The Dutch ICT in IBSE course (implemented with five batches already) is unique, since it is the only teacher-education course offered by several Dutch universities together, as far as we know. The Vietnamese ICT in IBSE course is unique as it is the only Master course of which design and materials were entirely developed outside the university. These institutionalisations do not happen often for general educational projects. These show not only the practical relevance of the basic design of the ICT in IBSE course for different educational and cultural contexts of pre- and in-service teacher education, but also suggest the possibility to have more-productive standardisation among teacher education courses.
Samenvatting

Achtergrond en onderzoeksvragen

Information en Communication Technology (ICT) en Inquiry-Based Science Education (IBSE) zijn al meer dan 30 jaar beschikbaar en worden prominent genoemd in formele curriculum documenten. Specialisten in onderwijs in de natuurwetenschappen zijn het grotendeels eens over de relevantie van integratie van ICT in IBSE voor leerlingen om onderzoekspraktijken te oefenen, onderzoeksvaardigheden te leren, en te begrijpen van wat onderzoek is. Niettemin wordt ICT in IBSE in de meeste landen nog steeds te weinig gebruikt en op relatief kleine schaal. Wanneer ICT wordt gebruikt, dan missen vaak essentiële onderdelen van onderzoeken. Betrokken factoren zijn o.a. a) beperkte curriculum tijd en beperkte voorbereidingsstijd van docenten; b) onvoldoende verwerking van IBSE-doelen in veel gebruikt lesmateriaal, lesmethoden, en toetsing (zoals de prescriptieve aard van lesmateriaal en onderwijsmethoden, dominantie van inhoud over onderzoeksdoelen); en c) onvoldoende voorbereiding en training van docenten in ICT in IBSE. Al deze factoren zullen moeten worden veranderd in samenhang om een juiste implementatie van ICT in IBSE in de klas te realiseren waarin manipulatie van apparatuur gepaard gaat met manipulatie van ideeën en begrippen en met het genereren en valideren van kennis.

In het PhD project richtten we ons op de voorbereiding en training van natuur- en scheikundedocenten in ICT in IBSE en ontwikkelden we een effectieve en korte cursus voor studenten in lerarenopleiding en docenten met uiteenlopende leservaring. In het onderzoek werd ICT in IBSE beperkt tot a) drie constructieve ICT-tools: meten met sensoren, videometen, en dynamisch modelleren, en b) gebruik van deze tools om onderzoek door leerlingen te ondersteunen. In een ICT in IBSE-activiteit moeten leerlingen niet alleen een rol hebben in het uitvoeren van het experiment of model, maar ook in het formuleren van onderzoeksvragen, het ontwerpen van het experiment of model, en in het interpreteren van de resultaten. We ontwikkelden een korte cursus die geaccommodeerd zou kunnen worden in de meestal overladen programma’s voor lerarenopleiding en geadopteerd zou kunnen worden als in-servicecursus. Onderwijs theorieën en producten, zoals deze ICT in IBSE-cursus, zijn niet altijd goed transporteerbaar vanwege de grote verschillen in onderwijs- en culturele context in scholen en landen. Daarom voerden we casestudies uit in Nederland, Slowakije, en Vietnam in pre-service en in-service lerarenopleiding. Op die manier konden we toetsen in hoeverre de cursus overdraagbaar is en in hoeverre de pedagogische principes waarop deze is gestoeld, generaliseerbaar zijn.

Het doel van het onderzoek was tweeledig. Het eerste doel was om een korte cursus te ontwikkelen die –met enkele aanpassingen- effectief zou zijn in sterk verschillende onderwijscontexten. Het tweede doel was om de validiteit van de pedagogische principes te toetsen die gebruikt werden om de volgende processen te sturen: a) het ontwerp, de implementatie, evaluatie, en optimalisatie van de cursus, en b) de aanpassing van de cursus voor toepassing in Nederland, Slowakije, en Vietnam. De pedagogische principes zijn op een hoger niveau van abstractie en bedoeld om generaliseerbaar te zijn naar andere onderwijs en culturele contexten. De ontwerp benadering van onderwijskundig onderzoek (“design research”) werd gebruikt omdat het een leidraad en wetenschappelijke redeneringen levert voor een dergelijk onderzoeks- en ontwerpproces. De onderzoeksvragen waren: Eerst, wat zijn de eigenschappen
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van een effectieve, korte cursus voor Nederlandse leraren in opleiding om ICT-tools te leren toepassen op een onderzoekende manier in IBSE? En ten tweede: in hoeverre is de cursus toepasbaar in verschillende onderwijs- en culturele contexten van per- en in-service lerarenopleiding in verschillende landen (zoals Nederland, Slowakije, en Vietnam)?

Ontwerp van cursus en onderzoek

Het algemene doel van de cursus werd gespecificeerd in vier doelen als volgt:

1. **Awareness**: deelnemers zijn zich bewust van de potentiële onderwijsvoordelen van gebruik van de ICT-tools in onderwijs in de natuurwetenschappen.
2. **ICT mastery**: deelnemers beheersen de vaardigheden die nodig zijn om het ICT-tool te gebruiken.
3. **ICT in IBSE**: deelnemers kunnen een onderzoekende les met ICT ontwerpen, uitvoeren, en evalueren.
4. **Motivatie**: Deelnemers zijn gemotiveerd voor verdere studie van de ICT tools en uitproberen daarvan in onderzoekende lessen met leerlingen.

Het ICT in IBSE doel (3) werd beschouwd als het hoofddoel van de cursus. Om dit doel te bereiken hadden de deelnemers een zekere minimumvaardigheid nodig met de ICT-tools (2). De doelen met betrekking tot awareness en motivatie om ICT te gebruiken waren gericht op lange termijn invloed op de onderwijspraktijken van de deelnemers. Het Coach platform voor meten met sensoren, videometen, en modelleren werd gebruikt met het beschikbare hulpmateriaal (bijvoorbeeld Coach inleidende, tutorial, en voorbeeldactiviteiten) en cursusmateriaal dat we zelf ontwikkelden (bijvoorbeeld formulieren voor ontwerpen en evalueren van ICT in IBSE-les).

De literatuur over ontwerponderzoek en professionele ontwikkeling van leraren leidde ons naar de volgende pedagogische principes (zie hoofdstuk 2) als de basis voor ontwerp, evaluatie, en optimaliseren van de ICT in IBSE-cursus.

1. **Een theorie-praktijkcyclus**: deelnemers moeten in de cursus minimaal een complete cyclus uitvoeren van ontwerpen, uitvoeren, en evalueren van een ICT in IBSE les. Deelnemers passen IBSE-theorie toe in een ontwerp voor een ICT in IBSE-les die ze ook uitproberen in de klas, evalueren, en rapporteren in de laatste sessie van de cursus.
2. **Gedistribueerd leren**: Deelnemers studeren in life sessies en voeren individuele taken uit tussen sessies met gebruik van de hulpmaterialen en in consultatie met de cursus docent. De leertijd is verdeeld tussen cursussessies en individuele taken, maar is ook zorgvuldig verdeeld over een langere periode om een goed geplande uitprobeer les in de klas mogelijk te maken.
3. **Eerst diepte**: Deelnemers worden geïntroduceerd in de mogelijkheden van de drie tools. Daarna specialiseren ze zich in één tool. De leertijd is wordt in de eerste plaats gebruikt voor grondige studie van een tool (een tool specialisatie) in plaats van meer oppervlakkige studie van de drie Coach tools, dus eerst diepte, dan breedte.
4. **Eigenaarschap van leren**: Deelnemers hebben de vrijheid te selecteren wat te leren en hoe te leren, met gebruik van het cursus scenario en de hulpmaterialen, om zo de cursusdoelen te bereiken. De deelnemers volgen een zelfbepaald
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De vier doelen, vier pedagogische principes, en hulpmaterialen vormen samen het algemene ontwerp van de ICT in IBSE-cursus.

Om de effectiviteit van de ICT in IBSE-cursus te bepalen en de validiteit en generaliseerbaarheid van de pedagogische principes en de overdraagbaarheid van het cursusontwerp naar andere onderwijscontexten, voerden we de Nederlandse, Slowaakse, en Vietnamese casestudies uit. De drie casestudies waren gerelateerd; de Nederlandse casestudie was de eerste en meest uitgebreide, gevolgd door de Slowaakse casestudie en de Vietnamese casestudie. Alle drie de casestudies a) betroffen dezelfde vragen over de implementatie van de pedagogische principes en cursusontwerp, bruikbaarheid van de hulpmaterialen, en bereiken van de cursusdoelen, b) gebruikten dezelfde evaluatie opzet, en c) gebruikten dezelfde instrumenten voor dataverzameling en analyse. De cursus evaluatie werd gestuurd door twee vragen:

A. In hoeverre werden de pedagogische principes toegepast zoals de bedoeling was?
B. In hoeverre werden de cursusdoelen van de ICT in IBSE-cursus bereikt?

Vraag B betreft de meting van effecten van de cursus op deelnemers als gevolg van de actuele implementatie van de pedagogische principes, het cursusontwerp, en de hulpmaterialen. De evaluatie van de werkelijke implementatie werd gestuurd door vraag A en was gebaseerd op een vergelijking tussen a) het bedoelde cursusprogramma en b) de werkelijke activiteiten van deelnemers in de cursus. Om te meten of de cursusdoelen bereikt waren, definieerden we eerst niveaus voor de prestatie op elk van de doelen. Deze definitie van niveaus was gebaseerd op theoretische overwegingen en de beperkingen in tijd van de cursus. Vervolgens verzamelden we de data en vergeleken die met de eerder gedefinieerde prestatieniveaus van de cursusdoelen en concludeerden dan welk niveau de deelnemers hadden bereikt. Hoofdstuk 3 presenteert dit evaluatieontwerp in detail met de instrumenten voor data verzameling en analyse (bijvoorbeeld, pre- en postcourse en follow-up vragenlijsten, observatie en video-opname van cursus sessies en van IBSE- lessen van deelnemers, formulier voor lesplannen van deelnemers, zelfevaluatie formulier voor de IBSE les, de ICT eindtoets voor elk tool en de Learning Activity Inventory). Met deze instrumenten werden data verzameld van diverse bronnen en door verschillende personen (researcher, cursusdocent, cursus deelnemers). We verzamelden zowel bedoelde als onbedoelde uitkomsten tijdens de implementatie van de cursus. De meeste uitkomsten werden gemeten door meer dan één instrument of observator en maakten dus triangulatie mogelijk.

In de Nederlandse casestudie operationaliseerden we de pedagogische principes in een eerste scenario voor de ICT in IBSE-cursus. Met scenario bedoelen we het programma voor de cursus en alle docent en deelnemer activiteiten en taken (hoofdstuk 3). We implementeerden en evalueerden de cursus met 40 natuurkunde/scheikunde leraren in opleiding gespreid over 4 cycli van de cursus. Van deze vier cycli waren cyclus 1 en 2 voor verbeterde afstemming van het cursus scenario. De cursus evaluatie (vragen A en B) en ervaringen met de cursus in cyclus 1 (wat werkte, wat niet, waarom) leidde tot suggesties voor revisie van de cursus. Deze revisie was bedoeld voor een meer getrouwe implementatie van de cursus in cyclus 2 en hield verband met veel factoren zoals diversiteit in de achtergrond en kennis/vaardigheden van deelnemers, school roosters, en curriculum tijd voor de ICT in
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IBSE-lessen van deelnemers in de school. Op dezelfde manier werd de evaluatie van cyclus 2 gestuurd door de cursusdoelen en pedagogische principes en dit resulteerde in verdere optimalisatie van het cursus scenario. In cyclus 3 bereikten we een implementatie van de vier principes zoals bedoeld. In deze cyclus maten we de summatieve effecten van de Nederlandse versie van de ICT in IBSE-cursus en slechts kleine veranderingen werden gesuggereerd voor verdere optimalisatie. De robuustheid van het cursusontwerp en de validiteit van de pedagogische principes werden getoetst in Cyclus 4 bij routine implementatie van de cursus zonder de extra hulp van de onderzoeker.

Het nieuwe begrip van hoe de cursus ontwikkeld was en waarom die effectief was (Nederlandse context) samen met het basiscursus ontwerp (inclusief cursus doelen, pedagogische principes, en hulmaterialen) maakte het mogelijk lokale versies van de ICT in IBSE-cursus te ontwikkelen in verschillende contexten. De ICT in IBSE-cursus werd aangepast en getoetst in a) twee cycli met totaal 66 natuurkunde/biologie/scheikunde docenten met uiteenlopende leservaring (1 – 33 jaar leservaring) in Slowakije (hoofdstuk 5). De twee cycli van de Slowaakse cursus werden al uitgevoerd onder routine condities zonder hulp van de onderzoeker. De ICT in IBSE-cursus werd toen aangepast en uitgeprobeerd in één cyclus in Vietnam met 22 Master studenten in natuurkundeonderwijs die of al 2 – 9 jaar hadden lesgegeven of direct uit de Bachelor lerarenopleiding kwamen (hoofdstuk 6). Toetsing van de drie lokale versies van de cursus maakte het ons mogelijk conclusies te trekken over a) de mate waarin de vier cursusdoelen waren bereikt, b) de validiteit en generaliseerbaarheid van de pedagogische principes, c) de overdraagbaarheid van het cursusontwerp, en d) de praktische relevantie van de cursus. Deze toetsing leidde ons tot nieuw begrip over in hoeverre de pedagogische principes helpen en sturen bij het aanpassen van de ICT in IBSE-cursus aan variërende omstandigheden (hoofdstuk 7).

Resultaten, discussie, en conclusies

Hoofdstuk 4 presenteert de Nederlandse casestudie die resulteerde in een verbeterd en succesvol cursus scenario waarin de Nederlandse deelnemers de cursusdoelen bereikten, ook wanneer de cursus gegeven werd onder routine condities (cyclus 4). De iteratieve evaluatie en aanpassingen van de Nederlandse cursus bevestigden de validiteit van de pedagogische principes in de Nederlandse context. De hulpmaterialen bleken nodig en nuttig in de toepassing van de pedagogische principes en voor de voldoende prestatie op cursusdoelen. Als conclusie: de vier cursusdoelen, de vier pedagogische principes, en het geoptimaliseerde scenario met de hulpmaterialen vormen de kerneigenschappen en het basisontwerp van een effectieve korte ICT in IBSE-cursus voor Nederlandse studenten. Resultaten van de iteratieve verfijning van de cursus laten zien dat het verfijnd afstemmen van de verdeling in tijd en individuele taken cruciaal is m.b.t. de tijdsverdeling in de cursus. Directe, gepersonaliseerde hulp (in life sessies en/of via e-mail) en doelgerichtheid (via hulp en tracking van taken en stimuleren) zijn cruciale factoren om de effectiviteit van het leerproces van deelnemers te waarborgen, vooral de kwaliteit van het ICT in IBSE-lesplan. Deze factoren creëren een balans tussen veel keuzevrijheid en passende begeleiding en dat is essentieel in het creëren van eigenaarschap.

De Nederlandse, Slowaakse, en Vietnamese contexten voor de ICT in IBSE-cursus verschillen in veel aspecten (bijvoorbeeld roostereisen, school condities, en eigenschappen
van deelnemers). Ten eerste, de Nederlandse cursus was beperkt tot 12 contacturen en 28 uur totale studietijd, maar was gespreid over 11 weken. De Vietnamese cursus was gecomprimeerd in 5 weken, maar 30 uur uit totaal 60 uur studietijd konden geroosterd worden voor “life” cursus sessies. De Slowaakse cursus had de minste beperkingen, zowel wat contacturen betreft (25 uit 40 studie-uren) als de spreiding van de cursus (15 weken). Ten tweede, de Nederlandse randvoorwaarden (bijvoorbeeld curriculumtijd, docentvoorbereidingstijd, nationale examens, leerling ervaring met ICT en IBSE, beschikbaarheid van apparatuur en software) waren niet ideaal maar wel voldoende. De Slowaakse schoolcondities waren onvoldoende en de Vietnamese condities waren slecht. Ten derde, de Vietnamese en Slowaakse deelnemers waren ervaren leraren, maar hun ICT-vaardigheden waren zwak. De Nederlandse deelnemers hadden meer ervaring met ICT-tools en voelden zich meer vrij om zelf te beslissen over hun lesdoelen en werkvormen. Maar zij misten leservaring en vooral klasmanagementvaardigheden. De Vietnamese leraren werken in een onderwijssysteem met een sterke hiërarchische cultuur en veel minder autonomie dan in het Nederlandse systeem. De lessen zijn sterk docent gecentreerd en er is geen traditie van open onderzoek of projecten in voortgezet onderwijs en in lerarenopleiding. Alle drie groepen misten praktische ervaring met IBSE met of zonder ICT, dus IBSE was een uitdaging voor hen. Voor alle drie de versies van de cursus waren heterogeniteit van deelnemers en beperkte tijd uitdagende contextuele factoren.

In de drie casestudies (hoofdstukken 4 – 6) werden de awareness en motivatie doelen van de ICT in IBSE-cursus bereikt zoals verwacht. De deelnemers konden relevante voordelen van de ICT-tools noemen en ze bedachten plannen en gingen door met het bestuderen van ICT-tools en geven van IBSE- lessen na de cursus. Met betrekking tot ICT-vaardigheid, de drie groepen deelnemers konden Coach redelijk vloeiend gebruiken na de cursus. Vergeleken met de Nederlandse deelnemers bereikten de Vietnamese deelnemers een hoger niveau van ICT-vaardigheid voor hun gekozen tool en de Slowaakse deelnemers bereikten een vergelijkbaar niveau maar dan met drie tools. Dit laat de effectiviteit zien van veel meer contacturen met directe en persoonlijke ondersteuning voor ICT-vaardigheid om te compenseren voor het lagere ICT start niveau van de Slowaakse en Vietnamese deelnemers. Dit stelde hen in staat het verwachte vaardigheidsniveau te bereiken.

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in een meer open vorm van onderzoek. Dit laat een duidelijk verschil zien in leraar/leerling gerichtheid en onderwijscultuur in de drie landen.

Hoewel reeds bekend met de theorie van IBSE, hadden de drie groepen problemen met het operationaliseren van echt onderzoek in lesplannen en nog meer in realisatie in de klas. Er waren veel verschillen tussen geplande en uitgevoerde ICT in IBSE-lesSEN, en deze kwamen voort uit bijvoorbeeld kortslijten van geplande onderzoeksomgevingen, taken die te veeleisend bleken, ambitieuze tijdsplanning, en ineffectieve communicatie met leerlingen. Maar de Nederlandse, Slowakse, en Vietnamees deelnemers konden de tekortkomingen in hun ICT in IBSE-lesSEN identificeren en relevante revisies suggereren voor hun toekomstige lesplannen. Het basisontwerp van de ICT in IBSE-cursus bleek effectief, praktisch, en overdraagbaar te zijn in de verschillende onderwijs en culturele contexten van per- en in-service lerarenopleiding in de verschillende landen. De cursus is geschikt voor verschillende groepen van leraren en past binnen de tijdsbeperkingen. In alle drie de casestudies werden de doelen bereikt tot een van tevoren bepaald acceptabel niveau, behalve dat er voor het ICT in IBSE-doel nog veel ruimte was voor verbetering.

We bereiden onze cursusdeelnemers voor op hun eerste ervaring met onderzoekend leren met ICT. De theorie-praktijk cyclus was waardevol in het creëren van bewustzijn over wat IBSE vereist en over verschillen tussen geleid en open onderzoek, en hoe leerlingen te betrekken in de planning en interpretatie van een experiment. We concludeerden dat onderwijsstelsel en cultuur de perceptie van leraren en implementatie van onderzoekend leren met ICT beïnvloeden. Dit resulteert in typische patronen van ICT in IBSE in de verschillende landen. De analyse van lesplannen en uitvoering met de Laboratory Activity Inventory liet aanzienlijke inconsistenties zien tussen intenties, lesplannen, specifiek van activiteiten en uitvoering, en bedoelde en uitgevoerde IBSE-lesSEN. Dit zijn hardnekkige problemen die wereldwijd zijn gerapporteerd (Abrahams & Millar, 2008; Abrahams & Reiss, 2012; Tamir & Lunetta, 1981); veel leraren hebben problemen met het operationaliseren van onderzoek in de klas, zelfs in landen als Engeland en de VS waar onderzoek al heel lang in de curricula is opgenomen. Onderzoeksresultaten van de Vietnamse casestudie laten de uitdagingen maar ook mogelijke oplossingen zien van de toepassing van IBSE in een hiërarchische onderwijscultuur (hoofdstuk 6). Natuurlijk duwt de ICT in IBSE-cursus met tijdbeperkingen de deelnemers nog onvoldoende in de richting van onderzoek met ICT. De prestaties van deelnemers in de cursus vormen een startpunt, meer theorie-praktijk cycli zijn nodig om hen verder te brengen in de richting van ICT in IBSE.

In ons onderzoek zijn de pedagogische principes niet allen valide als richtlijnen voor ontwerpen, implementeren, evalueren, en optimaliseren van de cursus in een bepaalde context, maar ook als richtlijnen voor effectieve aanpassing van de cursus aan uiteenlopende randvoorwaarden. Bij het aanpassen van de cursus aan een andere context kan de theorie-praktijk cyclus niet worden veranderd. Aan de andere kant kunnen de diepte-eerst en gedistribueerd leren principes wel in enige mate worden aangepast door de cursusdocent aan de specifieke context, zoals ingangs niveau en andere eigenschappen van deelnemers en roostereisen. Het eigenaarschap principe moet worden geactiveerd om de deelnemers een knop te geven om de cursus aan te passen aan eigen interesse en voorkennis/vaardigheden. De aanpassing met gedistribueerd leren en diepte-eerst creëert de eerste flexibele fase: ICT-
vaardigheid, deze kan verlengd worden (Sloveak casestudie) of gecomprimeerd worden (Vietnamese casestudie) om te compenseren voor een laag ingangsniveau van deelnemers, en hun activiteiten en taken aan te passen aan het bedoelde niveau van ICT-beheersing. Deze ICT-beheersing is nodig voor deelnemers om a) de ICT in IBSE-les te ontwerpen en uit te voeren, en b) de studie en gebruik van ICT-tools voort te zetten na de cursus. Van de vier cursusdoelen kan het ICT-beheersingsdoel bereikt worden in een gecomprimeerde cursus met voldoende contacturen, terwijl het ICT in IBSE-doel een verdeling van tijd vereist die een goed gepland en gerijpt lesplan mogelijk maakt en voldoende curriculumtijd voor keuze van een geschikte les voor uitproberen. De hulpmaterialen bleken nodig, nuttig en robuust te zijn in de verschillende contexten. Dit resultaat bevestigt dat het niet altijd nodig is materialen lokaal te ontwikkelen voor effectieve onderwijsinnovaties. Met enkele aanpassingen kunnen bestaande materialen gebruikt worden.

**Reflecties met betrekking tot resultaten en methoden**


Bij het begin van dit onderzoeksproject definitieerden we de unieke doelen van de te ontwikkelen cursus en een overzicht van ontwerpprincipes. Gebaseerd op deze doelen en criteria kozen we ontwerp onderzoek als middel om de cursus te ontwikkelen, evalueren, en optimaliseren. We begonnen het onderzoek en ontwerpproject met pedagogische principes en beëindigen het met deze principes als de kern van het basisonterwerp van de ICT in IBSE-cursus. Deze principes kunnen beschouwd worden als onafhankelijke en gevalideerde onderwijsproducten die lerarenopleiders kunnen adopteren en gebruiken voor bredere doelen dan alleen integratie van ICT in IBSE. De pedagogische principes creëren een theoretisch model onder het cursusontwerp dat richtlijnen en structuur geeft voor ontwerp, implementatie, evaluatie en optimalisering en helpt het ontwerp naar anderen te communiceren. De rol van de pedagogische principes is inderdaad essentieel. In ons ontwerponderzoek gebruikten we a) een robuustheidstap om de cursus uit te proberen onder routine omstandigheden en een generaliseerbaarheid en overdraagbaarheid stap om de cursus uit te proberen in verschillende
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programma’s of zelfs landen. We bereikten succesvolle uitkomsten met deze stappen. Daarom bevelen we aan robuustheid, en generaliseerbaarheid en overdraagbaarheid te toetsen als vast onderdeel van ontwerponderzoek.

Belangrijke beperkingen van het huidige onderzoek waren dat we alleen de kwaliteit van de ene theorie-praktijk cyclus toetsten en niet de gelegenheid hadden de verdere ontwikkeling van deelnemers te meten in latere ICT in IBSE-activiteiten in hun klassen, en dat leerling resultaten niet gemeten werden. Leren om les te geven door middel van IBSE heeft een langer traject nodig dan deze cursus, dus laten onze metingen slechts de start zien van de ontwikkeling van deelnemers. Om dezelfde reden was het niet zinvol om leerling prestaties te meten want verbetering van onderzoeksvaardigheden zou slechts zichtbaar worden na een serie van lessen en niet na één les.

Het is algemene praktijk dat elke lerarenopleiding zijn eigen wielen uitvindt. Onze onderzoeksresultaten door het ontwerpen/aanpassen, implementeren, en evalueren van de ICT in IBSE-cursus in Nederland, Slowakije, en Vietnam laten zien dat met een doordacht ontwerp en goed gekozen pedagogische principes, cursussen en andere onderwijsproducten kunnen worden aangepast en gedeeld. De vierde en vijfde cyclus van de Nederlandse cursus en de tweede cyclus van de Vietnamese cursus konden worden geïmplementeerd door lokale cursusdocenten zonder de onderzoeker. De derde Slowaakse cyclus wordt momenteel gepland binnen een nieuw project op nationale schaal waarbij het doel is ICT-tools te gebruiken in de verschillende disciplines van de natuurwetenschappen in Slowakije. De Nederlandse cursus (reeds geïmplementeerd in vijf cycli) is uniek want het is de enige lerarenopleidingscursus die –voor zover wij weten- gezamenlijk wordt uitgevoerd door verschillende Nederlandse universiteiten. De Vietnamese ICT in IBSE-cursus is uniek want het is de enige Mastercursus waarvoor ontwerp en materialen geheel werden ontwikkeld buiten de universiteit. Dit soort van institutionalisering gebeurt niet vaak voor onderwijsprojecten. Dit laat niet alleen de praktische relevantie zien van het basisonwerp van de ICT in IBSE-cursus voor verschillende onderwijs en culturele contexten van pre- en in-service lerarenopleiding, maar suggereert ook de mogelijkheid van meer productieve standaardisering van lerarenopleidingscursussen.
Acknowledgements

My hectic, challenging, and enjoyable ride in the Netherlands is ending after four years. At the close of this doctoral dissertation, I would like to acknowledge the people, who have guided me, supported me, travelled with me, waited for me to come home, and all together made this a memorable journey.

Primarily, I would like to convey my deepest gratitude to my supervisors, Jos Beishuizen, Ton Ellermeijer, and Ed van den Berg, who have supported me both academically and emotionally throughout the PhD trajectory. They provided me with freedom and autonomy to conduct the doctoral research from my low entrance and on my own pace. On the other hand, they critically challenged me with their comments and insights, patiently nurtured my research progress, and genuinely believed in my ability to complete a good thesis. Fruitful and insightful discussions with Jos, Ton, and Ed will be valuable for my future in research and teaching in Vietnam.

I am grateful to teacher educators, student teachers, experienced teachers, and secondary school pupils from the Netherlands, Slovakia, and Vietnam, who played different and crucial roles in the implementation of our ICT in IBSE course and who participated enthusiastically and responsibly during the case studies in the three countries. Without their willingness for participation and their consent for data collection, this research would not have been realised. Special thanks go to the course instructors: Ed van den Berg, Ton Ellermeijer, Ewa Kedzierska, Vincent Dorenbos, Ron Vonk, Peter Dekkers, and Ad Mooldijk (the Netherlands); Zuzana Ješková and Marián Kires (Slovakia); Quản Nguyễn Anh Thuần (Vietnam). I expect that our collaboration will continue for coming years.

My thanks go to the colleagues at the Vrije Universiteit Amsterdam for their sympathy, encouragement, and support: Joop van der Schee, Judith Schoonenboom, Silvester Draaijer, Annedien Pullen, Chiel van der Veen, and Vũ Trường Vân. On my first day at VU in spring 2012, Joop told me that the Netherlands had a good environment for growing flowers, scientific projects, and PhD theses. I was convinced and so I tilled and toiled the soil then planted the “PhD” seed and nursed the plant that resulted. Four years later, my “PhD” flowers are blooming. I hope that educational researchers, teacher educators, schoolteachers, and Joop will enjoy the results of my “gardening”.

I am indebted to the Ministry of Education and Training of Vietnam (MoET), the Vrije Universiteit Amsterdam (VU), and the Hanoi National University of Education (HNUE) for their financial and administrative support. In particular, I express my gratitude to Doret de Ruyter, Martijn Meeter, Caroline Vonk, Marianne Broekhuis (VU), chị Trần Thị Nga, chị Vũ Hồng Hạnh (MoET), Quản Nguyễn Anh Thuần (HNUE). Paul Logman and Pieter Hoogendoorn receive my thanks for their help in printing this dissertation. Thanks to iconarchive.com for the free download of country-flag icons used in the cover illustration.

My profound thanks go to Daday van den Berg, Ewa Kedzierska, and Ad van Wiggen for always welcoming me at their home. Warmness of the Dutch families has made my stay in the Netherlands a most enjoyable experience. Thanks to my CMA colleagues over the years
Acknowledgements

for being so friendly, good natured, and supportive. I have learnt from CMA how to build an effective and cohesive team and admired what amazing results such a small team can achieve. Thanks to CMA for allowing me to use new icons of Coach 7 for the cover illustration.

The completion of this doctoral dissertation would not have been possible unless I had been provided with sufficient academic background and continuous wholehearted support from my faculty of physics, HNUE. Sincerely, I would like to convey my gratitude to my home faculty and to special people there, who were my influential teachers and who are now my respected colleagues: thầy Nguyễn Ngọc Hường, thầy Phạm Xuân Quế, thầy Nguyễn Văn Biên, thầy Nguyễn Xuân Thành, thầy Lục Huy Hoàng, thầy Nguyễn Văn Minh.

A final word of thanks is for my parents, my wife, and my little children in Vietnam. Their unconditional love and countless sacrifices have been a source of strength and inspiration for my four PhD-years in the Netherlands. A few words in Vietnamese will communicate better: con cảm ơn bố mẹ! Phương, anh cảm ơn em! Phương An - Phúc An, bố yêu các con!

Once again, I would like to thank you all for supporting me in surviving, adjusting, and learning to work in the academic world of research. I am looking forward to effective application and further development of my knowledge gained through this doctoral research. My new ride is going to start soon!

Best regards, Trần Bá Trình (Trinh-Ba Tran)
Curriculum vitae

Trần Bá Trình was born on July 03, 1985 in Hanam province, Vietnam. He studied at secondary schools for gifted students in this province with specialisations in mathematics and physics. After finishing secondary education in 2003, he was accepted at Hanoi National University of Education (HNUE) to study in an honours Bachelor's programme in physics-teacher education. While studying, he developed a keen interest in ICT, laboratory, and their use in physics education. Trinh Tran graduated summa cum laude from this programme in 2007, and his Bachelor’s thesis on development of self-study courseware for student teachers won the national award for best research of undergraduate students. In the same year, he was accepted at the same university to work as a teacher educator at the faculty of physics and to enter his master programme on physics education. Trinh Tran completed his master degree two years later with a thesis about development of ICT-enhanced experiments for pupils’ investigations on gas laws.

Working at HNUE from 2009, he had a number of responsibilities, including conducting research projects funded by the university and the Ministry of Education and Training (MoET), teaching physics-education courses to student teachers, supervising undergraduate student research, and offering in-service training within HNUE’s and MoET’s teacher professional development programmes. In 2012, he started pursuing his doctoral study in the Netherlands, funded by MoET and supervised by Prof.dr. J.J. Beishuizen, Prof.dr. A.L. Ellermeijer, and Dr. E. van den Berg. The PhD project was aimed at the development of a course on integrating ICT into inquiry-based science education, carried out under the umbrella of the Dutch Interuniversity Centre for Educational Research (ICO), and facilitated by the Vrije Universiteit Amsterdam (VU) and the Dutch Centre for Microcomputer Applications (CMA). After completing his doctoral study at VU, he is going to continue his work at the faculty of physics, HNUE.
Curriculum vitae
Publications and presentations by Trinh-Ba Tran

Journal article

Peer-reviewed proceeding papers


Conference contributions related to this dissertation


Tran, T.B. (2015, October). Preparing pre-service teachers to integrate technology into inquiry-based science education: principles underlying an effective teacher-education course. Paper presented at the ICO national fall school 2015, Utrecht University, the Netherlands.


Other publications


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