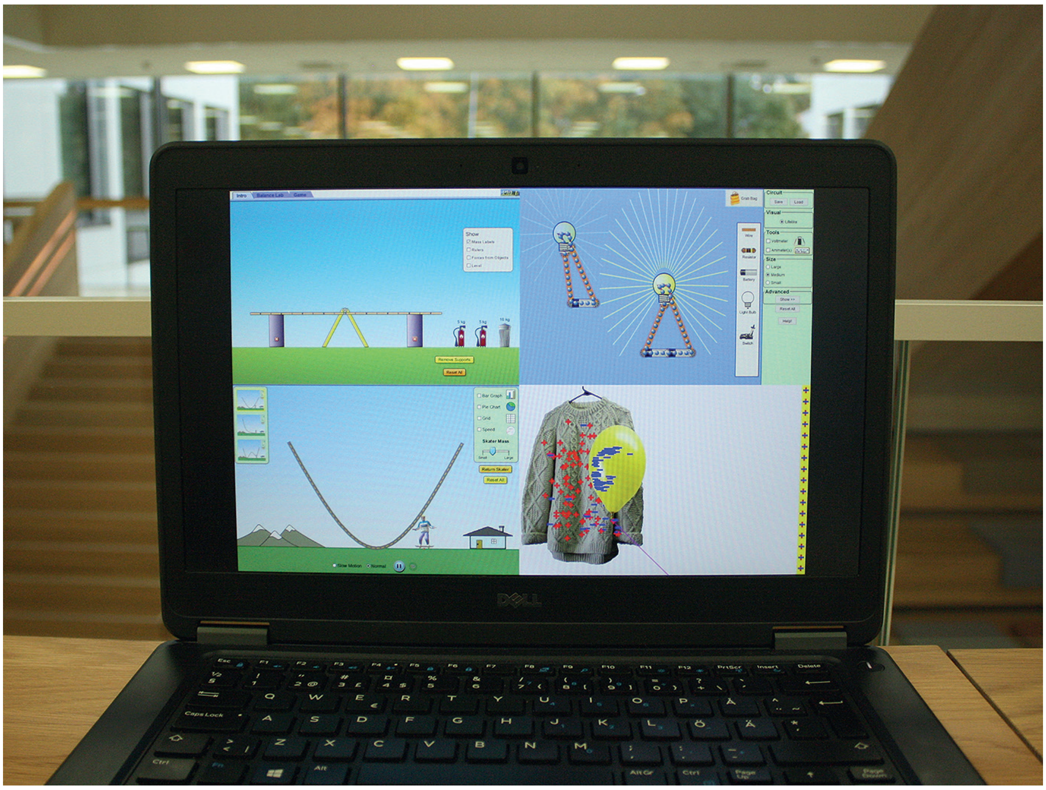
JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH
591

Antti Lehtinen

Pre-service Teachers and Guided Inquiry-Based Science Teaching with Simulations



JYVÄSKYLÄN YLIOPISTO

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Esitetään Jyväskylän yliopiston kasvatustieteiden ja psykologian tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston Ruusupuisto-rakennuksen Helena-salissa (RUU D104)
lokakuun 28. päivänä 2017 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Education and Psychology of the University of Jyväskylä,
in building Ruusupuisto, auditorium Helena (RUU D104), on October 28, 2017 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

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JYVÄSKYLÄ 2017

Editors
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Publishing Unit, University Library of Jyväskylä

Cover photo by Antti Lehtinen.

Permanent link to this publication: http://urn.fi/URN:ISBN:978-951-39-7182-3

URN:ISBN:978-951-39-7182-3
ISBN 978-951-39-7182-3 (PDF)

ISBN 978-951-39-7181-6 (nid.)
ISSN 0075-4625

Jyväskylä University Printing House, Jyväskylä 2017

ABSTRACT

Lehtinen, Antti
Pre-service Teachers and Guided Inquiry-Based Science Teaching with Simulations
Jyväskylä: University of Jyväskylä, 2017, 86 p.
(Jyväskylä Studies in Education, Psychology and Social Research
ISSN 0075-4625; 591)
ISBN 978-951-39-7181-6 (nid.)
ISBN 978-951-39-7182-3 (PDF)

The aim of this dissertation was explore the beliefs and practices of pre-service primary teachers on using simulations as a part of guided inquiry-based lessons. Even though research has shown that using simulations to learn science offers certain learning benefits compared to other forms of instruction, their use in Finnish schools is still rare compared to the international average. Teacher training has the potential to promote the use of simulations in primary classrooms. Internationally, research has been called for the role of teachers in learning and teaching with simulations. As a part of this dissertation, an intervention was designed to accustom a group of pre-service teachers to teaching science with simulations. As teacher beliefs play a critical role in the implementation of new technologies into classrooms, the connection of pre-service teachers' beliefs about their knowledge in different domains to their attitudes towards simulations was examined. The focus was also on how the pre-service teachers provided guidance for inquiry-based learning with simulations in the lessons that were a part of the intervention.

The findings show that the pre-service teachers' belief on their own technological knowledge correlates with their attitude towards simulations. As for providing guidance for inquiry-based learning with simulations, the findings demonstrate the important role teachers have on providing guidance that adapts to both the simulation and to the students' needs. The forms of guidance had also an effect on the communicative approach the pre-service teachers applied in the lessons. The results provide insight on the unique role of the teacher in science teaching with simulations but as well give guidelines to teacher educators on how to promote high quality inquiry-based science teaching with simulations through teacher training. These guidelines include improving the technological knowledge of pre-service teachers throughout their teacher training and ensuring that they are able to recognize the potential different providers of guidance have on supporting inquiry-based learning.

Keywords: Simulations, beliefs, inquiry-based learning, scaffolding

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PREFACE

When I was four years old, I wrote that when I grow up I want to be a postal worker. However, when I answered the same question again when I was five years old my dreams had changed: I wanted to become a researcher. Today, I identify more with the five-year-old me than the four-year-old me.

The journey from my Master's thesis to where I am now has been an exciting one. I have been lucky to have the chance to receive supervision from a group of experts who have guided me in every aspect of my still short academic life. I thank Professor Jouni Viiri, post-doctoral researcher Pasi Nieminen and University Lecturer Markus Hähkiöniemi from the bottom of my heart. Jouni opened a new world for me when during the supervision of my Master's thesis he introduced me to the exciting world of science education research. I also have him to thank for providing me with the funding that helped me get my dissertation work started. His laid-back but always professional attitude towards academic work is something for us all to aim for. Pasi always supported me during the past few years and reminded me that there much else in the world than just the academia. Markus pushed me forward with his sharp but friendly comments. I also benefited greatly from Post-Doctoral Researcher Sami Lehesvuori's expertise on dialogic teaching during the writing process of Article IV of this dissertation. I would also like to thank University Lecturer Sari Harmoinen from University of Oulu from her assistance on data collection for Article II of this dissertation.

I thank Professor Wouter van Joolingen and Professor Tuula Keinonen for agreeing to act as pre-examiners of my work. Their comments helped to finalize this dissertation. In addition, I would like to extend my warm thanks to Professor van Joolingen for agreeing to act as the opponent of my dissertation.

I am deeply grateful for the great atmosphere in our research group of Mathematics and Science Education Research in the Department of Teacher Education. Anna-Leena, Anssi, Hanna, Ilkka, Jenna, Joni, Kaisa, Laura and Sinikka, you have made every day working at the Department much more enjoyable as it would have been without you. Let's keep up the good spirit! I would also like to thank everyone else working at the Department of Teacher Education for creating such a pleasant place to work.

The Technology Industries of Finland Centennial Foundation, the Ellen and Artturi Nyyssönen Foundation and the Faculty of Education, University of Jyväskylä have financially supported my work. They have my deepest gratitude for their support. This dissertation would not have been possible without the co-operation of all the pre-service teachers and students who participated in the study. I thank them for volunteering for the study.

I am grateful for my parents for always encouraging me to fulfill my dreams. Their support means the world to me. I thank also my friends and the rest of my family for everything.

I thank Daft Punk for providing the soundtrack for writing this dissertation.

Finally, I thank my wife Auli for her never-ending support for my work. With her, I have gone through all the ups and downs of this journey. Having her by my side has helped me to reflect on my work. I will always be grateful for her for enduring all the evenings during the past few years when all I could talk about was related to research. I promise to come up with new topics after this.

Jyväskylä 14.09.2017
Antti Lehtinen

AUTHOR'S CONTRIBUTION

Design of the study and methods. The author designed the intervention in collaboration with the co-author of Article I, Pasi Nieminen. The author developed the surveys and questionnaires used in Articles I and II. The author chose the methods to use in the analysis of Articles III and IV.

Data collection. The author conducted all of the data collection (surveys, questionnaires, video recordings) in collaboration with Pasi Nieminen.

Data analyses. The author conducted the statistical analyses for Articles I and II. The author also conducted the analyses from the video data for articles III and IV in co-operation with the co-authors of those articles.

Findings and writing. The author wrote all of the articles with the co-authors commenting.

LIST OF ORIGINAL PUBLICATIONS

I Lehtinen, A., Nieminen, P. & Viiri J. (2016). Preservice Teachers’ TPACK Beliefs and Attitudes toward Simulations. *Contemporary Issues in Technology and Teacher Education,* 16(2), 151-171.

II Lehtinen, A., Nieminen, P., & Viiri, J. (2016). Pre-Service Primary Teachers' Beliefs of Teaching Science with Simulations. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto, & K. Hahl (Eds.), *Electronic Proceedings of the ESERA 2015 Conference*. Science Education Research: Engaging Learners for a Sustainable Future (pp. 1949-1959). ESERA Conference Proceedings, 4. Helsinki, Finland: University of Helsinki.

III Lehtinen, A., & Viiri, J. (2017). Guidance Provided by Teacher and Simulation for Inquiry-Based Learning: a Case Study. *Journal of Science Education and Technology*, 26(2), 193-206. doi:10.1007/s10956-016-9672-y

IV Lehtinen, A., Lehesvuori S., & Viiri, J. (2017) The Connection between Forms of Guidance for Inquiry-Based Learning and the Communicative Approaches Applied - a Case Study in the Context of Pre-Service Teachers. *Research in Science Education*. Online advance publication. doi:10.1007/s11165-017-9666-7

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ORIGINAL PAPERS

1 INTRODUCTION

The aim of this study is twofold. The first aim is to explore pre-service primary teachers' (PSTs') beliefs about using simulations to teach science, about their beliefs in their technological, pedagogical and content knowledge and the possible connection between these beliefs and their attitude toward simulations. The second is to better understand the guidance provided by PSTs' in guiding inquiry-based lessons where simulations are used to conduct investigations. Through achieving these aims, teacher training can be developed alongside advancing research on what the teachers' role is in guiding inquiry-based learning with simulations.

Briefly stated, simulations used in science teaching are computer programs that mimic the behavior of a real system (de Jong & Lazonder 2014). They allow students to interact with a simplified model of the system and observe how changing variables affects the outcomes of the simulation (van Berkum & de Jong 1991). The research regarding the learning effects of computer simulations in science education will be discussed in more detail in a later chapter of this dissertation, but in general, computer simulations enhance students' conceptual understanding and motivation (Rutten, van Joolingen & van der Veen 2012). The motivational effect of simulation usage in science teaching makes them a possibly a part of a solution to a local problem: while Finnish fourth graders achieve good scores in the cognitive and content areas of the international Trends in International Mathematics and Science Study (TIMSS) study, Finnish fourth graders also have the most negative attitudes toward learning science (Mullis et al. 2016). At the moment, simulations are not widely used in Finnish primary schools. Even though the percentage of 4th grade students who use them at least monthly to study natural phenomena has risen in Finland in the last few years according to the TIMSS study (from 15% of fourth graders in 2011 to 22% in 2015), the number is still below the average for the countries participating in TIMSS (25% in 2011 and 28% in 2015) (Martin et al. 2012, Mullis et al. 2016).

The new Finnish Core Curriculum which has been in use since August 2016 (Finnish National Agency for Education 2014) emphasizes the use of technology in teaching: throughout grades 1 to 9 students should be taught how to use information and communication technology to collect information and conduct investigations. In lower secondary school (grades 7 to 9) the use of simulations to support learning in physics and chemistry is explicitly mentioned as one of the aims of these subjects. The possible effect of the new curriculum affects on the use of simulations remains to be seen. At the moment, Finnish teachers are not participating in professional development programs that could promote the use of simulations: just 5% of Finnish fourth graders in 2011 and 8% in 2015 were taught science by a teacher who had participated in professional development programs regarding intergrating information technology into science during the last two years (Martin et al. 2012, Mullis et al. 2016). According to the Teaching and Learning International Survey (TALIS), Finnish teachers spend less time attending professional development programs than the international average (OECD 2014). This highlights the importance that initial pre-service teacher training has in equipping teachers with the attitudes, skills and practices they need to teach science effectively using simulations. Teachers' attitudes toward technology are seen as a predictor of their use in teaching (Teo, Lee & Chai 2008, Teo 2009, Zacharia 2003).

While the learning effects of simulations have been extensively researched, less research has been undertaken on teaching with simulations. Due to the interactive and engaging nature of simulations, they are usually seen as a good fit to be used to conduct investigations in an inquiry-based setting (de Jong et al. 1998, Rutten, van Joolingen & van der Veen 2012). Still, more information is needed on how to teachers can be incorporated into other classroom activities how they can guide students in using simulations to learn science (Rutten, van Joolingen & van der Veen 2012, Smetana & Bell 2012). Also, to design effective learning environments where inquiry-based learning is supported as well as possible, more research is needed on how to guide the learning of "softer skills" such as argumentation and epistemic practices (Bereiter & Scardamalia 2006, Hmelo-Silver, Duncan & Chinn 2007) and how the provided guidance can be distributed between the teacher and the simulation (Puntambekar & Kolodner 2005, Tabak 2004, van Joolingen, de Jong & Dimitrakopoulou 2007).

This doctoral dissertation consists of four articles (I–IV). Articles I and II report on an intervention carried out in autumn 2014 with a group (n = 40) of PSTs at the Department of Teacher Education, University of Jyväskylä. Article I deals with how the PSTs' beliefs about their technological, pedagogical and technological knowledge (TPACK) develop during the intervention and how they are related to their disposition toward using simulations. Article II deals with beliefs that PSTs have about teaching science with simulations. It also includes the results from a similar teaching experiment carried out at the University of Oulu and discusses the similarities and differences between the two cases.

Articles III and IV are focused on analysing the guidance for inquiry-based learning provided by the PSTs in the lessons that were a part of the aforementioned intervention. Article III reports on what forms of guidance were provided for inquiry-based learning by both a particular simulation and the PSTs and how the guidance was distributed between these two providers through different patterns. Finally, Article IV analyses the role that the guidance provided by PSTs plays in the communicative approaches they applied in a lesson and how through providing non-specific forms of guidance they are able to engage in dialogic interaction with the students.

The overall aim of this doctoral dissertation is to give suggestions to teacher educators about desigining pre-service teacher training to promote the use of simulations in guided inquiry-based science teaching. These suggestions are based on the results from each article regarding both pre-service teachers' beliefs about and practices guiding inquiry-based science learning with simulations.

2 THEORETICAL BACKGROUND

The following four sections will present the main theoretical background and literature related to this doctoral dissertation. Each section covers one topic: what simulations used in science education are and what research has been conducted regarding them, what does research say about teachers' knowledge and beliefs regarding teaching with technology, what is inquiry-based learning and how can it be supported with guidance and what is the role of classroom communication in teaching science.

2.1 Simulations in science education

The definition for simulations used in science education has on one hand evolved throughout history and on the other stayed similar. The first definition by Gagné (1962) came from military education and stated that simulations have three characteristics: 1) a simulation represents a real situation in which operations are carried out, 2) a simulation provides users with certain controls over the problem or situation and 3) a simulation omits certain distracting variables which are irrelevant or unimportant for the particular instructional goals. McGuire (1976) wrote about simulations in science education and defined simulations as *"placing the individual in a realistic setting where he is confronted by a problematic situation which requires his active participation in initiating and carrying through sequences of inquiries, decisions, and actions"*. Lunetta and Hofstein (1981) simply stated that *"simulation is the process of interacting with a model that represents reality"*. de Jong and van Joolingen (1998) were the first to explicitly state that simulations run on computers when they defined computer simulations as *"a program that contains a model of a system (natural or artificial; e.g., equipment) or a process"*. Clark, Nelson, Sengupta and D' Angelo (2009) defined them as *"computational models of real or hypothesized situations or phenomena that allow users to explore the implications of manipulating or modifying parameters within the models"*, while finally de Jong and Lazonder (2014) used the definition of *"a* *computer program that mimics the behavior of a real system where students can experiment (…) by changing the values of input variables and observing the effect on one or more output variables".*

In all of these definitions, some fundamental characteristics have stayed the same: 1) simulations represent reality through a model, and 2) the user can interact with the simulation. The models used in simulations are usually simplified models of reality; Chen (2010b) reviewed over 230 educational physics simulations and found that 80% of those simulations represented ideal cases e.g. frictionless and air resistance –free movement. 99% of the reviewed simulations contained no error sources. The upside of this simplification is that it allows students to focus on the relevant (chosen by the producers of the simulation) feature of the phenomena under study (Finkelstein et al. 2005). On the other hand a simplified model represented through a simulation might not activate students' prior conceptions, which is vital in promoting conceptual change (Chi 2008, Vosniadou 2002), or it can make the gap between theory and reality so large that students doubt the authenticity of the simulation (Srinivasan et al. 2006). Simulations can also visualize the otherwise invisible phenomena (e.g. electrons moving inside a wire or gas molecules moving in a container) or change the temporal properties of phenomena (e.g. decay of molecules) to make them investigable in science classrooms (de Jong, Linn & Zacharia 2013, van Berkum & de Jong 1991). Figure 1 shows four different physics simulation from the PhET simulation database (University of Colorado Boulder 2017). These four simulations showcase the simplified nature of simulations. For example, in the simulation at the bottom left air resistance is not taken into account when modelling the movement of the skater on the ramp. Figure 1 also showcases how simulations can be used to visualize the otherwise invisible. For example, in the simulation at the bottom right electric charges are visualized as plusses and minuses.

The interactivity of simulations also brings with it its pros and cons. The fact that simulations enable students to change the variables and observe the consequences promotes active participation in the investigations carried out in the simulation, which is essential for inquiry-based learning (de Jong & Lazonder 2014, Rutten, van der Veen & van Joolingen 2015). On the other hand, the interactivity of simulations raises the need for metacognitive skills to utilize the simulation environment efficiently. These needs include the cognitive load of understanding and working with the interface of the simulation (Hegarty 2004) and the ability to discern crucial elements of the simulation from the less crucial (Lowe 2004). These factors raise the importance of supporting learning with simulations by providing guidance (more on this in section 2.4).

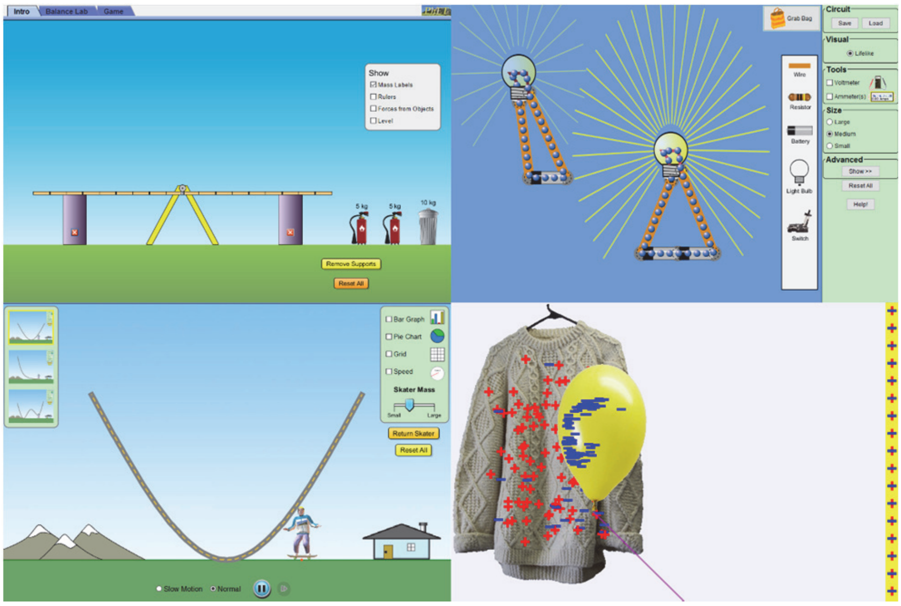


FIGURE 1 Examples of simulations from the PhET (University of Colorado Boulder 2017) database.

de Jong and van Joolingen (1998), Smetana and Bell (2012) and Rutten, van Joolingen and van der Veen (2012) have conducted reviews of previous research on simulations for science education. In 1998 de Jong and van Joolingen concluded in the first review that *"the general conclusion that emerges from these studies is that there is no clear and univocal outcome in favor of simulations"*. Fourteen years later Smetana and Bell stated that simulations are at least as effective and in most cases even more effective than traditional methods in teaching content knowledge, at least as effective as traditional methods in developing science process skills and usable to facilitate conceptual change in students. Their review also included guidelines for research-based practice with simulations: they should be used to supplement other learning activities, include learning support, encourage reflection and promote cognitive dissonance. Finally, Rutten, van Joolingen and van der Veen conclude that in all of the studies they reviewed, computer simulations enhanced learning outcomes and motivation scores. Most of the studies cited in these reviews have been with students in secondary school or older. Less research has been conducted on primary-age students and simulations (Zacharia, Loizou & Papaevripidou 2012) but Jaakkola (2012) has shown that primary-aged learners from Grades 4 to 6 also benefit from using simulations to learn science.

Traditionally simulations used in science education have been seen as alternatives to traditional laboratory work (Jaakkola 2012). Similar (Klahr, Triona & Williams 2007, Zacharia & Constantinou 2008) or even better (Chang et al. 2008, Finkelstein et al. 2005) conceptual learning outcomes when simulations are compared to laboratories have been reported in multiple contexts. Research has also been conducted on whether combining simulations (either in parallel or sequentially) with laboratory work would produce better learning outcomes choosing one method over the other. The results show that combining simulations with laboratory work sequentially produces better conceptual learning outcomes than laboratory work alone (Zacharia 2007, Zacharia, Olympiou & Papaevripidou 2008) and that combining simulations with laboratory work in parallel produces better conceptual learning outcomes than either one on their own (Jaakkola & Nurmi 2008).

One of largest databases for ready-made simulations for science education is the Physics Education Technology project (PhET) run by the University of Colorado in Boulder, Colorado, USA (University of Colorado Boulder 2017). Other sources for computer simulations used in science education include Molecular Workbench (The Concord Consortium 2013) and Physlet Physics (Christian & Belloni 2013)

2.2 Teachers' knowledge and beliefs about teaching with technology

Lee Shulman (1986) formulated the concept of pedagogical content knowledge (PCK) to represent the domain of teachers' knowledge that deals with representing the content matter in a way that makes it comprehensible to others. It also includes understanding what makes learning specific content areas easy or difficult for others. As technology has advanced, it has brought new possibilities as well as challenges for education. To use technology to its full potential, teachers need not just have knowledge about technology per se but also about how to use it to enhance the teaching of specific content (Mishra & Koehler 2006). Thus, the PCK framework was complemented with a technological component, and a technological pedagogical content knowledge (TPCK or TPACK) framework (Figure 2) (Koehler & Mishra 2009, Mishra & Koehler 2006, Pierson 2001) was formed.

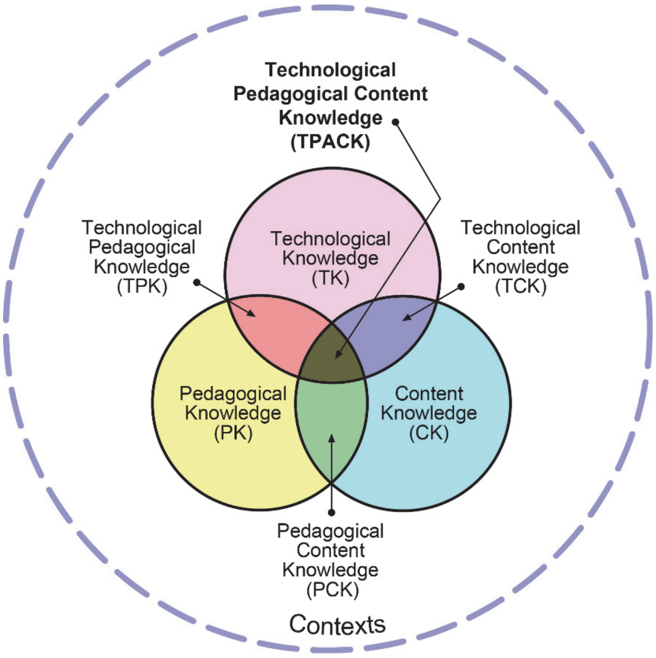


FIGURE 2 An illustration of the TPACK framework. Reproduced by permission of the publisher, © 2012 by tpack.org.

The three circles in Figure 2 (Koehler & Mishra 2009) represent technological (TK), pedagogical (PK) and content knowledge (CK). In their intersections are pedagogical content knowledge (PCK, as Shulman formulated it), technological content knowledge (TCK, understanding how technology affects practices and knowledge of e.g. physics) and technological pedagogical knowledge (TPK, understanding how particular technologies used in a particular way affects teaching and learning). In the middle of the figure where all three circles intertwine is the domain of technological PCK (TPACK, understanding how a particular technology can be used in teaching and learning specific content). Even though the TPACK framework as formulated by Koehler and Mishra has been criticized for having too many domains of knowledge that are very difficult to separate from one another, it has allowed the conceptualization of the benefits that technology can bring for teaching and learning (Archambault & Barnett 2010, Brantley-Dias & Ertmer 2013).

Even though the TPACK framework is focused on teacher knowledge, teacher beliefs must also be taken into account when discussing teaching with technology. In this dissertation, beliefs are defined as the link between objects and attributes (for example “Using computers (objects) is hard” [attribute] (Koballa 1989). The distinction between knowledge and beliefs is a complicated matter with many differing conceptualizations about their connections (see the review by Jones and Leagon (2014) for further discussion). In this dissertation, the definitions used for these concepts state that beliefs and knowledge are intertwined (Pajares 1992, Verloop, van Driel & Meijer 2001, Zelkowski et al.

2013). Knowledge is primarily a cognitive structure, while beliefs have both cognitive and affective components (Jones & Leagon 2014, Pajares 1992, Rokeach 1968). From a social point of view, beliefs do not require a consensus, while knowledge usually does (Nespor 1987). Individually, as when discussing teacher knowledge, knowledge is more related to factual propositions than beliefs (Meijer, Verloop & Beijaard 2001).

Similarly as with knowledge and beliefs, there are multiple definitions for the relationship between beliefs and attitudes (Jones & Leagon 2014). In this dissertation, the definition used for attitudes states that they describe positive or negative feelings toward a person, group, policy, instructional strategy or particular discipline (Fishbein & Ajzen 1975, Zacharia 2003). While beliefs have both cognitive and affective components, attitudes are mainly affective (Fishbein & Ajzen 1975). Table 1 lists the main concepts regarding beliefs and practices used in this dissertation along with their definitions and sources of the definitions.

TABLE 1 The definitions and their sources for the main concepts used in this dissertation regarding beliefs and practices

Concept	Definition	Source
Belief	The link between objects and attributes based on evaluation and judgement, both cognitive and affective	Pajares 1992, Koballa 1989,
Knowledge	Intertwined with beliefs but primarily cognitive and based more on factual propositions	Pajares 1992, Meijer, Verloop & Beijaard, 2001
Attitude	Positive or negative feelings toward e.g. a person or instructional strategy	Fishbein & Ajzen 1975
Practice	What people do instead of who they are or what they think	Grossman et al. 2009

As the TPACK framework was developed, researchers started planning measurements regarding the framework. TPACK has been measured through self-report measures, performance assessments, interviews and observations (Koehler, Shin & Mishra 2012). Out of these measurement types, self-report measures have been the most common way to measure TPACK (Voogt et al. 2013). The self-assessment of TPACK also measures teachers' personal beliefs about their knowledge (Abbitt 2011b, Zelkowski et al. 2013), as knowledge and beliefs are inextricably intertwined (Pajares 1992). If self-report measures were to be taken as objective measures of knowledge, they would be limited in the respondents ability to accurately assess what they do and do not know (Abbitt 2011b). In this dissertation, PSTs' self-reported TPACK is conceptualized as their belief about their knowledge in the different domains of the TPACK framework. This is done to highlight the affective component of beliefs compared to knowledge. It also allows the compatible parts of the literature on teacher beliefs to be used. This conceptualization is somewhat connected to the concept of self-efficacy (confidence to perform certain tasks) (Pajares 1992) but is less related to any certain tasks and more to the PSTs' perception of their own knowledge.

The connection between beliefs, knowledge and practice has been modelled from different perspectives. Fullan (1982) argued that changes in teachers' knowledge and beliefs preceded changes in their teaching practices. Guskey (1986) saw it the other way around: changes in classroom practices preceded changes in teachers' beliefs. Through empirical data, Clarke and Hollingsworth (2002) formulated the Interconnected Model of Teacher Growth (presented in Figure 3), which connects teachers' knowledge and beliefs to their classroom practices through two different mediating processes: enactment and reflection. The process of enactment is defined as putting a new idea or belief or newly encountered practice into action. The process of reflection is defined similarly as Dewey (1910, p. 6) did as active, persistent and careful consideration. These two processes link four different domains: the external domain (new information or stimulus), the personal domain (knowledge, beliefs and attitudes), the domain of practice (professional experimentation in the classroom) and the domain of consequence (salient outcomes). One possible path of teacher growth according to the model by Clarke and Hollingsworth is that new experiences by an external stimulus (such as how to use simulations in science teaching) are enacted in practice (planning and implementing a lesson where simulations are used). The teacher then reflects upon the experimentation and draws conclusions based on the salient outcomes (such as how the students reacted to the investigations with the simulations). These salient outcomes are then reflected upon, and the teacher's knowledge, beliefs and attitudes regarding the topic are revised accordingly. This path highlights the role that professional experimentation of new practices and reflecting upon the salient outcomes of that experimentation can play regarding teachers' knowledge, beliefs and attitudes.

Other models for conceptualizing the adoption of technology into teaching exist—for example, the Technology Acceptance Model (Davis 1989), which is based on the Theory of Reasoned Action (Ajzen & Fishbein 1980). The Interconnected Model of Teacher Growth was chosen as the theoretical framework for Article II in this dissertation for its focus on external stimulus (such as interventions) and its focus on teacher beliefs.

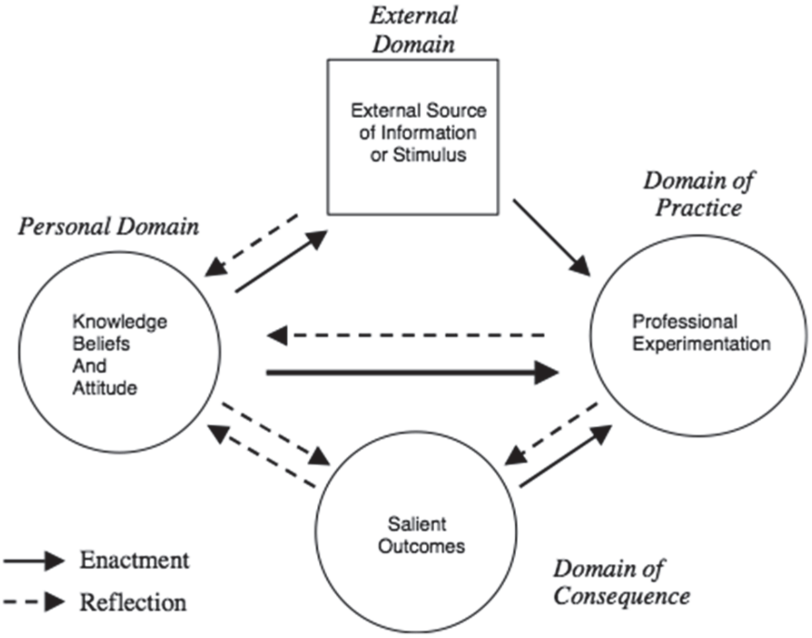


FIGURE 3 The Interconnected Model of Teacher Professional Growth by Clarke and Hollingsworth (2002).

Coming back to specifically teaching with technology, teachers' internal factors (for example attitudes and beliefs) pose a challenge larger than access to hardware and software or training and support for technology integration into classrooms (Ertmer & Hruskocy 1999, Ertmer et al. 2012). Empirically, Chen (2010a) showed that pre-service teachers' beliefs about technology affect their use of technology, and Abitt (2011a) demonstrated that pre-service teachers' self-assessed TK predicts their self-efficacy toward technology. Regarding simulations, Zacharia (2003) states that teachers' attitudes about simulations are connected with their use. Kriek and Stols (2010) found that a belief in simulations being useful for teaching (which can be seen as being connected with teachers' attitude toward simulations) was connected with simulation usage.

Different suggestions have been made as to how to promote using technology in teaching as a part of pre-service teacher studies. Active involvement in technology-enhanced lesson or course design and modelling teaching with technology has been shown to promote TPACK development (Kontkanen et al. 2014, Voogt et al. 2013). Sointu et al. (2017) argue that differences within the PST population in ICT self-efficacy should be taken into account during teacher training. More specifically regarding science teacher training, Maeng, Mulvey, Smetana and Bell (2013) argue that emphasizing the role of technology in learning as a part of science methods courses during teacher training develops pre-service teachers' TPACK. Regarding simulations in particular, Zacharia, Rotsaka and Hovardas (2011) state that pre-service teachers should be exposed to good practices regarding the use of simulations and showed how simulations could efficiently and effectively achieve learning goals. These previous research results show the effect that beliefs have on the use of technology in teaching.

2.3 Inquiry-based learning and guidance

Simply put, inquiry-based learning is an educational strategy where the students follows procedures and practices similar to those of scientists (Keselman 2003). Students are expected to actively participate in constructing knowledge by conducting experiments which are based on research questions or hypotheses (de Jong & van Joolingen 1998, Pedaste et al. 2015, Rönnebeck, Bernholt & Ropohl 2016). As the whole scientific process is very complex from a pedagogical point of view, it is often divided into smaller phases in which each has their own characteristics. The often-used 5E learning cycle model (Bybee et al. 2006) lists five phases: Engagement, Exploration, Explanation, Elaboration and Evaluation. To synthesize the existing frameworks for inquiry-based learning, Pedaste et al. conducted a literature review on 60 articles dealing with inquiry-based learning. Their framework for inquiry-based learning consists of five phases and is listed in Table 2.

TABLE 2 Phases of inquiry-based learning and their definitions by Pedaste et al. (2015)

Phase	Definition
Orientation	Stimulating curiosity about a topic and coming up with a problem statement
Conceptualization	Stating theory-based questions and hypotheses
Investigation	Planning an experimentation and collecting and analysing data from the experiments
Conclusion	Drawing conclusions from the data and comparing them with the research questions or hypotheses
Discussion	Presenting findings by communicating with others and/or reflecting on the whole process or its phases

Inquiry-based learning and practices related to it have been advocated in policy papers as an effective and beneficial way to learn science (Finnish National Agency for Education 2014, National Research Council 1996, National Research Council 2000, NGSS Lead States 2013). Learning goals for inquiry-based learning can be categorized into three categories (Gyllenpalm, Wickman & Holmgren 2010) (the first two being specific for inquiry-based learning and the third generic for all science learning):

- learning to do inquiry (for example, learning how to design and plan experiments)
- learning about inquiry (for example, how scientific knowledge is constructed)
- learning through inquiry (for example, conceptual knowledge)

Critics of inquiry-based learning argue that asking students to discover or construct scientific knowledge is ineffective due to its high cognitive load (Kirschner, Sweller & Clark 2006, Mayer 2004). This criticism is aimed at unguided inquiry-based learning where the teacher's role is minimal, and the students are not supported in their learning activities. As students do often have problems with activities associated with inquiry-based learning (such as generating hypotheses, designing experiments or interpreting data) (de Jong & van Joolingen 1998), learners need to be supported in these activities. This support is often called *scaffolding* (Hmelo-Silver, Duncan & Chinn 2007, Lin et al. 2012, van de Pol, Volman & Beishuizen 2010) or *guidance* (de Jong & Lazonder 2014, Lazonder & Harmsen 2016, Zacharia et al. 2015). With younger learners with less experience on these activities, the need for support can be greater than with more experienced learners.

Historically, scaffolding is defined as a process which enables a novice to solve problems, carry out tasks or achieve goals which are otherwise beyond his/her unassisted efforts (Wood, Bruner & Ross 1976). A more contemporary definition of scaffolding in teacher-student interaction defines it as a support for learning that is adjusted to the needs of the learners, which fades away gradually and where the responsibility of learning is gradually transferred to the learner (van de Pol, Volman & Beishuizen 2010). Lazonder and Harmsen (2016) define guidance as *"any form of assistance offered before and/or during the inquiry learning process that aims to simplify, provide a view on, elicit, supplant, or prescribe the scientific reasoning skills involved"*. The core concept is the same: providing support for learning by the teacher, software or accompanying learning material. An example of guidance provided by a simulation is the ability to hide or show some elements of the simulation, such as positive and negative charges in the "Balloons and Static Electricity" PhET simulation (Figure 1, bottom right). The possibility to choose either to visualize or not these elements of the phenomenon offers the chance to first examine the phenomenon without the charges being visible and only after this visualize the charges. This simplifies the learning process. In this dissertation the term *guidance* is used, because it is commonly used in research literature to describe learning support for inquiry-based science learning (de Jong & Lazonder 2014, Lazonder & Harmsen 2016, Zacharia et al. 2015), but the important contribution to the topic made by the literature on scaffolding is acknowledged and used where appropriate.

Guidance for inquiry-based learning can have different forms or types. Reid, Zhang and Chen (2003) distinguished between *interpretative support* (help with structuring knowledge and interpreting data), *experimental support* (help with designing experiments and drawing conclusions) and *reflective support* (help with reflecting on one's own process and becoming aware of one's own progress). de Jong and Njoo (1992) formulated two categories for learning support: *directive support* (steers the students toward a certain direction/answer) and *non-directive support* (does not steer toward any particular direction but instead helps the students perform certain learning actions). Recently, de Jong and Lazonder (2014) formulated a typology for forms of guidance which organizes the forms based on the specificity of support the students need to perform the inquiry process. Lazonder and Harmsen (2016) modified the names of the forms slightly, and their typology is presented in Table 3.

TABLE 3 Forms of guidance and their descriptions by Lazonder and Harmsen (2016) (based on de Jong & Lazonder (2014))

Form of guidance	Description
Process constraints	Reduce the complexity of the learning process by limiting the number of options the learners need to consider
Status overview	A real-time progress report of the learning process or evolving knowledge which makes the progress apparent
Prompts	Reminders to carry out certain actions or learning processes
Heuristics	Suggestions on how to perform a certain action or learning process, such as hints or reminders
Scaffolds	Taking over more demanding parts of a learning process often by structuring the activity
Explanations	Giving out target information and/or specifying how to perform an action

Alongside different forms, guidance (or scaffolding) can also be provided by different sources such as teachers or software. Different sources of guidance have different affordances for providing guidance; for example, teachers can obtain information about students' performance from multiple sources compared to software, which affects their ability to adapt their guidance to the students' needs (Ruiz-Primo 2011). Puntambekar and Kolodner (2005) use the term *distributed scaffolding* for instructional designs that include guidance from multiple providers. This distribution can manifest in three different patterns (Tabak 2004). These patterns are listed in Table 4.

TABLE 4 Patterns of distributed scaffolding and their descriptions by Tabak (2004)

Pattern of distributed scaffolding	Description
Differentiated scaffolds	Each learning need is targeted by its own form and source of guidance
Redundant scaffolds	Multiple forms target the same need, but they can be enacted at different points in time
Synergistic scaffolds	Multiple forms of guidance co-occur and interact with each other

Different meta-studies have come to the conclusion that supporting inquiry-based learning with guidance increases learning outcomes when compared to both traditional lessons (Alfieri et al. 2011, Furtak et al. 2012) and un-guided inquiry (Alfieri et al. 2011, Furtak et al. 2012, Lazonder & Harmsen 2016). Also, Zacharia et al. (2015) conducted a literature review on guidance provided by software for learning science with simulations and online laboratories and found that most of the studies on the subject showed a positive effect on learning or performance. Two further research topics stand out from the literature on guidance for inquiry-based learning with simulations. Firstly, the role of the teacher in teaching science with simulations and guiding inquiry-based learning with them is in need of research (Chang 2013, Rutten, van Joolingen & van der Veen 2012, Smetana & Bell 2012). Secondly, even though the benefits of providing guidance for inquiry-based learning are quite clear when learning outcomes are measured, more research is needed on how providing guidance can also facilitate learning "softer skills" (Bereiter & Scardamalia 2006), such as collaboration or epistemic practices (Hmelo-Silver, Duncan & Chinn 2007). These epistemic practices include knowledge that the inquiry learning processes that the students enact in science classrooms are similar to the practices of actual scientists (Bell, Lederman & Abd-El-Khalick 1998) and that scientific knowledge can change if new evidence is produced or old evidence is interpreted differently (Furtak et al. 2012).

2.4 Science classroom communication

Lemke's (1990, p. 16) widely cited phrase: "learning science means learning to talk science" showcases the importance of talk and communication in learning science. The view that science teaching is not an individual process but instead a sociocultural activity is prevalent in modern science education research (Alexander 2006, Lehesvuori 2013, Mercer 2000, Mortimer & Scott 2003). This view stems from Vygotsky's work (1978) on learning through interaction and communication.

The traditional and still dominant way of teaching science sees the teacher as an authoritative figure holding the scientific knowledge (Lehesvuori 2013, Mercer, Dawes & Staarman 2009, Muhonen et al. 2017, Wells & Arauz 2006). This sort of transmissive pedagogy has been linked with loss of interest in learning science (Lyons 2006). When looking at inquiry-based learning—which entails constructing new knowledge by planning investigations based on students' previous knowledge, conducting these investigations and drawing conclusions based on data—it is difficult to put this into practice if the teacher is seen as the authoritative figure who holds the scientific knowledge. Inquiry-based teaching is not just about having the students conduct experiments (which might be overemphasized (Saari & Sormunen 2007)) but instead working with students' existing views and enabling them to experiment on research problems based on these views (Lehesvuori et al. 2011) (see also Table 2). There is also empirical evidence for this: in a study by Blanchard et al. (2010), students in an inquiry-based setting whose teachers paid more attention to their prior knowledge, were open to their ideas and encouraged them to come up with their own ways of investigation achieved better learning outcomes. A small-scale study by Kiemer, Gröschner, Pehmer and Seidel (2015) found a connection between an increase teachers' discourse practices that activated students and the students' perceived autonomy, competence and intrinsic learning motivation. Thus to teach inquiry-based science effectively, teachers should understand how to facilitate discussions that promote cognitive processes in line with inquiry-based learning (Oliveira 2010).

Current research sees dialogic teaching as a possible method to promote these cognitive processes (Alexander 2006, Lehesvuori 2013, Mortimer & Scott 2003). Scott, Mortimer and Aquiar (2006) define *dialogic* discourse in a classroom as a discourse that is open to different perspectives and points of view. Through dialogic discourse students' previous knowledge can be taken into account with the aim of building new knowledge together on top of that. In contrast with dialogic discourse is *authoritative* discourse, which is focused on only one point of view and does not allow the exploration of ideas (Scott, Mortimer & Aguiar 2006). Typically, authoritative discourse takes into account only the prevailing school science point of view. The teacher seizes upon students' point of view if they are in line with the prevailing view; otherwise they are discarded.

As discussed at the end of the previous chapter, how guidance for inquiry-based learning relates to learning how scientific knowledge is constructed (epistemic practices) or how students collaborate or work together is still in need of research. The dialogic approach to classroom communication has the potential to promote learning these skills. The dialogic–authoritative continuum regarding classroom discourse bears resemblance to the continuum of non-specific–specific guidance (de Jong & Lazonder 2014, Lazonder & Harmsen 2016). When a teacher applies an authoritative approach to classroom communication, he/she can be seen as taking the side of the prevailing scientific view. The students can be led toward this view by providing more specific forms of guidance, such as scaffolds or the direct presentation of information. On the other hand, providing more non-specific forms of guidance, such as process constraints or prompts, gives more space to the students' own points of view, which can then be explored through a dialogic approach. This possible connection between forms of guidance provided and communicative approaches applied has not been studied even though the importance of studying the connection between dialogic teaching and scaffolding (or guidance) has been recognized (Bakker, Smit & Wegerif 2015).

Mortimer and Scott (2003) also differentiate between *interactive* and *non-interactive* approaches to communication. The interactive approach to communication allows the participation of more than one person (for example a teacher and students), while the non-interactive approach excludes the participation of other people. When these two dimensions to classroom communication are combined, four different categories for the communicative approach can be defined. These four categories are presented in Table 5.

TABLE 5 Communicative approaches to classroom discourse by Mortimer and Scott (2003) and their descriptions

Communicative approach	Description
Authoritative / Interactive (A/I)	A question-answer routine where learners' responses are evaluated by the teacher and ideas diverging from the scientific point of view are rejected. The focus is on the scientific view.
Dialogic / Interactive (D/I)	Learners' ideas are elicited and then explored without evaluation. The teacher is not trying to achieve a specific point of view but instead works with the learners' views.
Authoritative / Non-Interactive (A/NI)	The teacher lectures and presents the scientific content. The focus is on a specific point of view.
Dialogic / Non-Interactive (D/NI)	The teacher revisits and summarizes contrasting points of view, such as learners' own ideas.

One potential tool for opening up dialogic discussions are teachers' questions. "Open" (Chin 2007) or "real" (Furtak & Shavelson 2009) questioning, which aims to stimulate, explore and prompt students' thinking without a pre-determined answer, could promote dialogic discussions. On the other hand, "closed" (Chin 2007) questioning, where the answer is pre-determined, does not often lead to dialogic interaction. Teachers' questions can also start different patterns. The so-called IRF triadic dialogue (Lemke 1990) consists of the teacher's *Initiation* (for example a question), the students' *Response* and the teacher's *Feedback*. This pattern is characteristic for an authoritative approach to communication where the teacher evaluates students' responses (Lehesvuori et al. 2013). But if the teacher follows up a student's response with another prompt or question (so called IRPRP-sequence, where P stands for prompt (Mortimer & Scott 2003), differing from the definition of prompt by Lazonder and Harmsen (2016)), the teacher builds up the discussion based on the student's answer, which is in line with a dialogic approach to communication (Lehesvuori et al. 2013).

Scott and Ametller (2007) argue that meaningful science teaching should include both authoritative and dialogic episodes. They advocate *opening up* discussions by a dialogic approach where students' existing knowledge is elicited, and they are given a chance to work with these possibly conflicting views. Also important is the *closing down* of discussions, where the scientific content is isolated and clarified. This comes from the fact that science is largely based on a collection of accepted ways of thinking and talking about phenomena. This "opening up" and "closing down" of discussions can happen before and after the investigation phase of inquiry (Lehesvuori et al. 2011), but there can also be multiple instances of discussion that are "opened up" and then "closed down" during a lesson (Scott & Ametller 2007). Wegerif (2010) also emphasizes that teachers should be able steer the dialogic discussions towards scientific conclusions and set boundaries for dialogue. Small-scale results also suggest that combining authoritative and dialogic communicative approaches provides better learning outcomes than either approach alone (Furtak & Shavelson 2009).

Closely connected with opening up and closing down discussions is the concept of pedagogical link-making (Scott, Mortimer & Ametller 2011) that describes the practices of teachers and learners in making connections between ideas through interactions in the classroom. Three different forms of pedagogical link-making are identified:

- Supporting knowledge building,
- Promoting continuity, and
- Encouraging emotional engagement.

As an example, knowledge building can be supported by, for example, making links between every day (i.e. students' existing ideas) and scientific ways of explaining or by making links between different scientific concepts. Through pedagogical link-making, ideas elicited during the opening up part of discussions can be connected with the scientific view in the closing down part. This link between of existing knowledge and new ideas is central to the constructivist perspective to learning (Larochelle, Bednarz & Garrison 1998).

When talking about inquiry-based learning, Lehesvuori, Ratinen, Kulhomäki, Lappi and Viiri (2011) formulated a holistic model of dialogic inquiry-based teaching that includes the "opening up" and "closing down" phases separated by an experimentation phase. Still, their model offers only limited tools for detailed lesson planning, which is essential for implementing inquiry in practice (Zubrowski 2007). Connecting the forms of guidance provided by teachers through their actions to dialogic and authoritative approaches to classroom communication and thus to the "opening up" and "closing down" phases of inquiry-based lessons could give some guidelines that could potentially be used for planning meaningful inquiry-based science lessons.

3 AIM AND RESEARCH QUESTIONS

The research aim of this study stems from the presented theoretical background. Figure 4 showcases the most essential concepts, topics and their connections presented in the previous chapter.

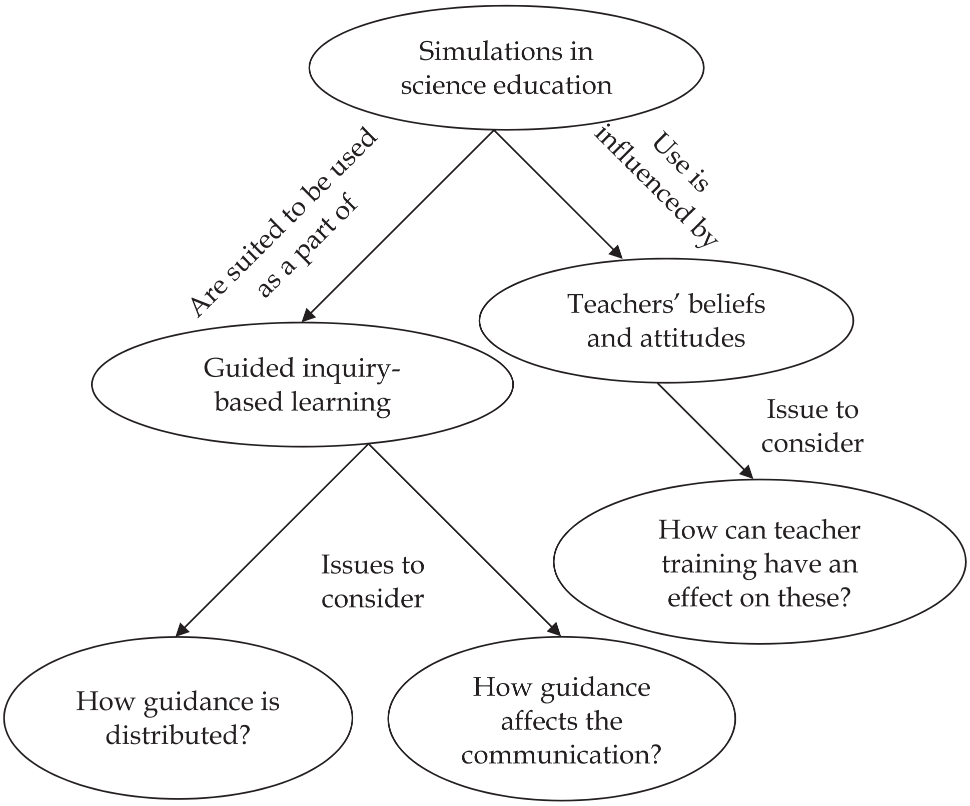


FIGURE 4 The essential concepts, topics and their connections

As presented in section 2.1, simulations offer possibilities to enhance both science learning outcomes and the motivation to study science. However, as presented in Chapter 1, in Finland simulations are not used to the same degree in primary school as in other countries, and Finnish fourth graders in general have been found to dislike learning science. As Finnish teachers do not extensively participate in in-service professional development courses, the burden of promoting the use of simulations lies mostly with pre-service teacher training. Research sees teachers' beliefs and attitudes as having an impact on their intention to use technology in their teaching. TPACK has gained a prominent status as the framework through which teachers' knowledge and beliefs in different domains can be conceptualized. Considering this, this dissertation deals with PSTs' beliefs on teaching science with simulations (Article II) and how their beliefs on their TPACK divided into different domains developed during an intervention aimed at promoting the use of simulations in science teaching and how their TPACK beliefs were connected with their attitude toward simulations (Article I). Together, these two articles address the following research question (RQ 1):

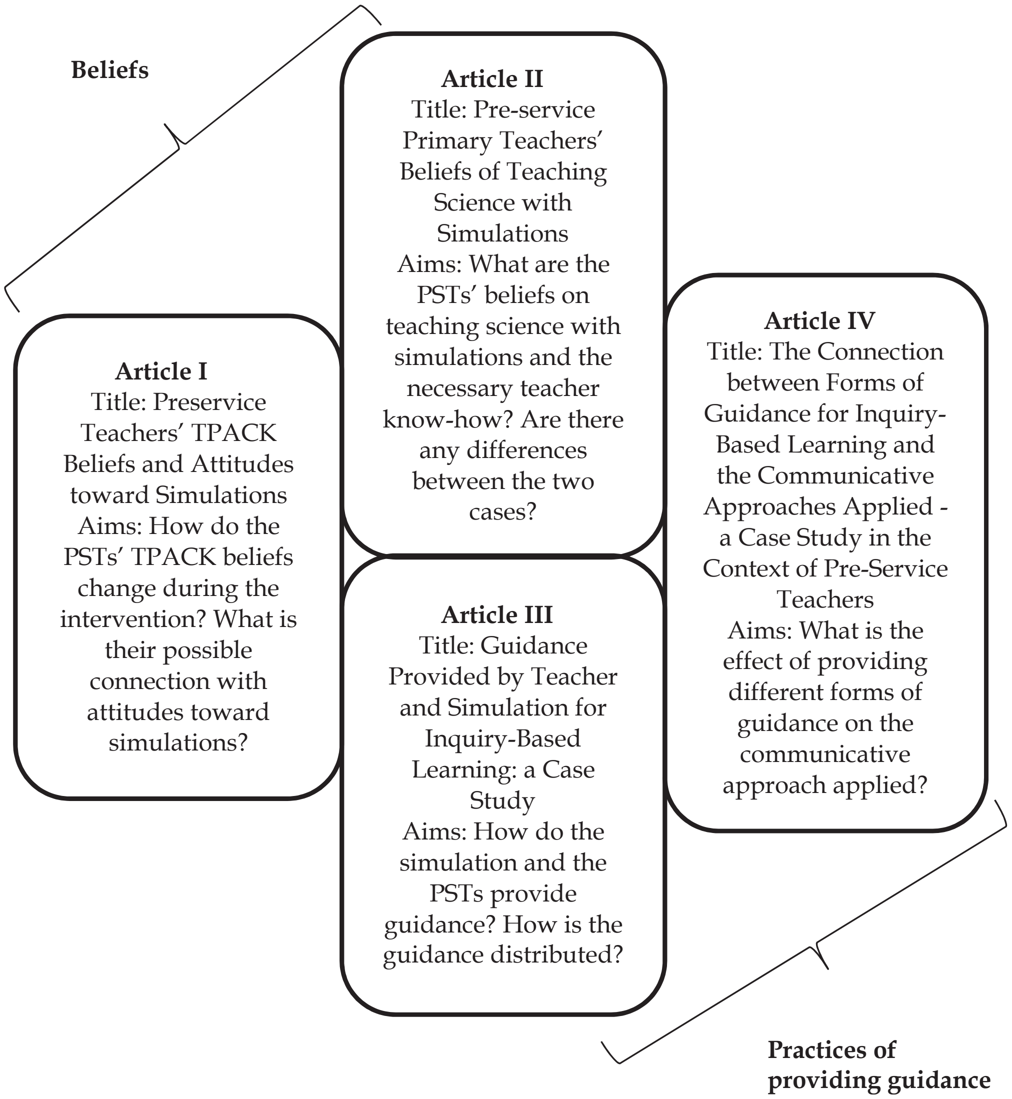
1) What are PSTs' beliefs on teaching science with simulations, and what is the connection between their beliefs on their TPACK to their attitudes toward simulations?

Sections 2.3 and 2.1 dealt with inquiry-based learning, supporting it with guidance and the importance of communication and interaction for science learning. As the benefits for learning provided by simulations are well established (see section 2.1), research is needed on how teachers and students use simulations and what their roles are during investigations with them. Since supporting inquiry-based learning with guidance has been highlighted as a crucial aspect of the pedagogical approach and simulations are well suited for inquiry-based learning, the dissertation focuses on guided inquiry-based learning with simulations. Two articles deal with this topic: Article III, about how guidance is provided by both the PSTs and the simulation and how the different patterns for distributed guidance manifest, and Article IV, about how different forms of guidance provided by PSTs affect the communicative approaches they apply. This could have an effect on the possibilities for students to come across the epistemic practices of science. These two aspects are considered important in studying guidance for inquiry-based learning with simulations as outlined in the previous chapters. Together these two articles address the following research question (RQ 2):

2) How do different aspects of guidance for inquiry-based learning with simulations manifest in the pre-service teachers' practices?

Figure 5 presents the articles' titles, aims and relation to each other.

The broader aim of this dissertation is to *give guidelines on how to improve teacher training related to teaching science with simulations*. The two research questions deal with different aspects of preparing PSTs to use simulations to teach science. The results to in regard to RQ 1 give insight into how pre-service teacher training can be developed in such way that PSTs develop a positive attitude toward integrating simulations into their science teaching. They also give insight into how different first experiences of teaching with simulations can affect PSTs' views on the know-how needed to teach science with them. On the other hand, the results concerning RQ 2 give insight into PSTs' practices in guiding inquiry-based learning with simulations. Research on learning with simulations has shown that properly guided inquiry-based teaching is optimal for learning science with simulations. PSTs should be taught how to provide learners with guidance that benefits their learning. The results to RQ 2 can be used to develop future pre-service teacher training that takes this into account.



Article I
Title: Preservice Teachers' TPACK Beliefs and Attitudes toward Simulations
Aims: How do the PSTs' TPACK beliefs change during the intervention? What is their possible connection with attitudes toward simulations?

Article II
Title: Pre-service Primary Teachers' Beliefs of Teaching Science with Simulations
Aims: What are the PSTs' beliefs on teaching science with simulations and the necessary teacher know-how? Are there any differences between the two cases?

Article III
Title: Guidance Provided by Teacher and Simulation for Inquiry-Based Learning: a Case Study
Aims: How do the simulation and the PSTs provide guidance? How is the guidance distributed?

Article IV
Title: The Connection between Forms of Guidance for Inquiry-Based Learning and the Communicative Approaches Applied - a Case Study in the Context of Pre-Service Teachers
Aims: What is the effect of providing different forms of guidance on the communicative approach applied?

FIGURE 5 Descriptions of the articles and their relations.

4 CONTEXT AND METHODS

This chapter presents the study's context: the Finnish PST training and the course of the main intervention implemented at the University of Jyväskylä (JYU) (a similar teaching experiment with simulations carried out at the University of Oulu (UO) reported in Article II is also briefly introduced). The methods in the analysis for each of the four articles are also presented.

4.1 Finnish pre-service teacher training

In Finland, studies in primary teacher training programs last about five years, and the qualification requires a degree of Masters of Education (300 ECTS credits) (Evagorou et al. 2015). The program provides qualification to teach all subjects in grades 1 to 6. Primary school teacher training is organized by the Faculties of Education in eight different universities. The teacher training program consists of multiple different modules, such as language and communication skills and both major and minor subject studies. Topics related to different school subjects are taught in a compulsory study module titled *"Studies in subjects and theme areas taught in the primary school"* (Silander & Välijärvi 2013). The size of whole module is 60 ECTS credits (or about one year of studying). The pedagogy and content of science are taught as a part of this module. There are no national standards or obligatory courses for primary teacher students except the aforementioned module, and instead each university offers its own courses with varying amounts of ECTS credits. In JYU, in fall 2014 when the main intervention was conducted, the science methods course for PSTs awarded 9 ECTS credits (Department of Teacher Education, University of Jyväskylä 2013). As each university and Faculty of Education can set the content of this science methods course independently, there are differences in the division between teaching the content knowledge and pedagogy of science between different universities, but the differences are not major. In JYU, in the curriculum used in fall 2014 the science methods course focused on how to plan and implement science lessons in which appropriate teaching and assessment methods are used (Department of Teacher Education, University of Jyväskylä 2013). The science methods course culminates in planning and implementing a teaching-learning sequence. Usually due to lack of resources (and the fact that the PSTs go through teaching practice as a separate module) this sequence is implemented by the PSTs in groups with their peers. The intervention that is reported in this dissertation was integrated into the science methods course and culminated in planning and implementing an inquiry-based lesson with actual primary-aged students. Outside of the group of PSTs who participated in this study, simulations are introduced to the PSTs as a part of a lecture about ICT and science teaching, but the PSTs' chances to implement lessons where simulations are used differ from year to year and group to group. During their teaching practice, which usually takes place in Teacher Training Schools connected with the universities, the PSTs might teach some science lessons, but this is not mandatory.

4.2 Participants of the study

The participants of this main intervention were 40 PSTs, of which 39 completed all the study questionnaires and instruments (34 females, 5 males, $M_{age} = 24.1$, $SD_{age} = 4.2$) studying in JYU. The gender representation is typical for Finnish primary teacher education. The students were majoring in Special Education but had chosen primary teacher studies as their minor. The content of the primary teacher studies is the same even if one chooses them as their major or minor subject. The PSTs were in different phases if their studies, ranging from their second year to the fifth year of the five-year Master of Education program. Their teaching experience ranged from under six months to over two years, with most of them having taught for under six months. None of them had taught science with simulations before the intervention, and just one PST reported having used simulations before (to learn science in high school). The others had no experience of using simulations to learn or teach science.

A teaching experiment with simulations from UO is reported in Article II. There 18 PSTs (16 females, 2 males, $M_{age} = 22.6$, $SD_{age} = 2.6$) completed the questionnaire after their teaching experiment. Their teaching experience also ranged from under six months to over two years, with most of them having taught for under six months. One of them had previous experience of learning science with simulations from high school; the others did not have any experience with simulations.

4.3 Intervention to promote the use of simulations

The main intervention was implemented from September 2014 to November 2014 in period of eight weeks. The 40 PSTs took part in the intervention in two groups of 20 PSTs each. The content of the intervention was similar for both groups. Two teacher educators (the author and Dr Pasi Nieminen) planned and executed the intervention and were present in all of the meetings and lessons that were part of the intervention.

The intervention consisted of weekly group meetings (duration 90 minutes) which focused on inquiry-based learning in teaching science with simulations, with the overall goal being to plan and implement an inquiry-based science lesson for primary students where simulations were used to conduct at least a part of the investigation. The PSTs were not introduced to any typology for different forms of guidance, but in the first 90-minute meeting about the principles behind inquiry-based learning the role of the teacher in inquiry-based learning was brought up (as one who guides the learning process where the students should themselves be the ones discovering new information). The 5E learning cycle model (Bybee et al. 2006) (see section 2.2) was showcased as an example of how to plan and implement an inquiry-based lesson, but the PSTs did not have to plan their lessons based solely on the 5E model. The process of planning the lessons was supported by multiple instances of feedback from the teacher educators and peers. This was done to surpass some of the difficulties PSTs encounter with planning and implementing inquiry-based lessons, such as how to get the learners to generate hypotheses or draw conclusions (García-Carmona, Criado & Cruz-Guzmán 2017, Lehesvuori et al. 2011).

The outline of the intervention is described in Table 6. The TPACK survey and the end survey will be presented in section 4.4.

TABLE 6 The course of the intervention

Week	Event / meeting	Subject of the event / meeting
1	TPACK pre-test	
1	Inquiry-based learning	Introduction to inquiry-based learning in science (the 5E model was used as an example)
2	Simulations in science teaching	A chance to try out some PhET simulations and a brief introduction to teaching science with simulations
3	Subgroups and lesson topics	Each of the two groups of 20 PSTs were further divided into four subgroups of 5 PSTs each. These subgroups were each given a topic to plan an inquiry-based lesson around, in which they had to use a predefined simulation
4	Planning the lessons	The subgroups had revised the scientific content of their lessons and presented their preliminary lesson plans alongside the most common misconceptions
5	Planning the lessons	The subgroups presented their final lesson plans to their peers and the teacher educators and received comments about them
6–7	Implementing the lessons	
7	TPACK post-test	
8	Reflection and the end survey	The PSTs reflected on their experiences of the intervention with their peers

The lessons, which were central to the intervention, were planned and implemented in subgroups of five PSTs each. Four different topics were assigned to the subgroups, one for each of the four subgroups in the larger group of 20 PSTs. This meant that as a part of the intervention two lessons were implemented about the same topic. As a part of the planning process the PSTs were instructed to reflect on their pre-conceptions on the topic of their lessons (Driver et al. 1994), to revise the scientific content related to the lessons and to use some provided scientific articles to identify what common misconceptions primary-aged students have on their topic. The PSTs were also instructed to use a particular PhET simulation (University of Colorado Boulder 2017) in their lessons. PhET simulations were used due to their availability mostly in Finnish as well as their derivation from a comprehensive database of simulations for different topics, which the PSTs can then utilize in their practice. The topics of the lessons were decided together with the teachers of the primary classes where the lessons were implemented. They also fit the Finnish primary school science curriculum. The topics of these lessons and the PhET simulations used in them are described in Table 7. The simulations are pictured in Figure 1.

TABLE 7 The topics of lessons planned and implemented as a part of the intervention and the simulations used in them

Topic	PhET simulation used
Static electricity	Balloons and Static Electricity
Forms of energy	Energy Skate Park: Basics
DC circuits	Circuit Construction Kit (DC Only)
Balance	Balancing Act

The lessons were implemented in two different primary schools in eight different primary classes ranging from third grade (mostly 10-year olds) to sixth grade (mostly 13-year-olds). The class sizes were between 15 and 20. The PSTs were given five laptops (from the university and tested so the simulations worked) to run simulations during their lessons, so school resources were not an issue.

In the teaching experiment (carried out in spring 2015) at UO reported in Article II, the PSTs had to also plan and implement an inquiry-based lesson where simulations had to be used. One meeting (about 90 minutes) was used to familiarize the PSTs with different simulations. The main differences between the main intervention and the teaching experiment at UO were that at UO, the PSTs had to plan a series of lessons (6 to 10), where in some lessons simulations had to be used. There was no requirement of inquiry-based teaching involved. In the lessons implemented in UO, the PSTs used devices from the schools in which the lessons were implemented. They were not given any particular simulation to use in the lesson but instead searched the simulations to be used in their own. At JYU the PSTs planned just one inquiry-based lesson, where they used a designated simulation that could be run using devices from the university which were known to work with the simulations.

4.4 Data collection

A TPACK survey (Appendix 1) administered through an online form at weeks 1 and 7 of the intervention was used to collect data about the development of the PSTs TPACK beliefs for Article I. The PSTs' self-reported TPACK in the different domains of knowledge is conceptualized as their beliefs related to these domains. This is based on the literature on the connection between PSTs' self-reported TPACK and both their beliefs and self-confidence (Graham et al. 2009, Zelkowski et al. 2013) and knowledge and beliefs in general (Pajares 1992).

The TPACK self-report instrument used is based on two previous TPACK instruments. The first is a TPACK self-report instrument for in- and pre-service science teachers developed by Lin, Tsai, Chai and Lee (2013), which contained 27 items divided into the seven domains of the TPACK framework. Lin et al. reported satisfactory validity and reliability for their instrument. Their instrument was modified from the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al. 2009), which was aimed at measuring self-reported TPACK regarding all subjects, not just science. The second instrument was a self-report TPACK instrument by Zelkowski, Gleason, Cox and Bismarck (2013), which was aimed at pre-service mathematics teachers. Zelkowski et al. reported good internal reliability for the test but noted that they were not able to produce meaningful factors for the PCK, TPK and TCK domains. Their final survey contained 22 items restricted to only the TK, CK, PK and TPACK domains. The validity of the survey used in this dissertation could not be tested through statistical means due to the small size of the study group, but the instruments (Lin et al. 2013, Zelkowski et al. 2013) from which the survey was derived had acceptable validity. The reliability of the survey was determined through calculating Cronbach's alphas for the scales of different domains of knowledge. All of the scales on the pre- and post-tests met the threshold criteria commonly adopted of Cronbach's alpha > .80, indicating good reliability.

The TPACK instrument used to measure the PSTs' beliefs about their TPACK in Article I contained 29 seven-level Likert items (28 positively phrased and 1 negatively phrased) divided into the domains of CK, PK, TK and TPACK. The decision not to include the three other domains of the TPACK framework was based on the critique by Brantley-Dias and Ertmer (2013) that the domains of the framework are difficult to distinguish from each other and the fact that the survey instrument was partly adapted from Zelkowski et al. (2013), who could not produce meaningful factors for these domains. The items about different areas of mathematics (algebra, geometry etc.) in Zelkowski et al.'s (2013) study were changed to items about different science subjects, since these subjects (physics, chemistry, biology and geography) are taught together in Finnish primary schools from grades 1 to 6 and they are covered in the science methods course at JYU.

The end survey (Appendix 2) administered at the end of the intervention on paper at week 8 and after the teaching experiment at UO was used to collect data on the PSTs attitude toward using simulations (usefulness of simulations in science teaching and their disposition toward integrating simulations in their teaching) using two seven-level Likert items. The end survey also had open questions on the possibilities and weaknesses of simulations and the necessary teacher know-how (the Finnish term used in the survey was "tietotaito") to teach science with them. Our conceptualization of teacher know-how is close to the conceptualization of teachers' practical knowledge (Van Driel, Beijaard & Verloop 2001). The PSTs could give as many answers as they wanted to the open questions.

For Articles III and IV the data were collected through recordings made on the lessons implemented by the PSTs as a part of the intervention. Data from different lessons were used in different articles. All eight lessons (lasting about 45 minutes each) were video recorded using two static cameras (one at the back of the classroom and another in the front of the classroom). These cameras recorded the whole-group activities and the associated talk. The small group activities (usually investigations with the simulation in groups of 2 to 4 students with one PST guiding the work) were recorded using screen capture software running on the laptops where the simulations were run. This type of recording enable the synchronized recording of the talk during the simulation activities and the activities themselves. From all eight lessons, the entire amount of video data was about 25 hours.

5 SUMMARY OF RESULTS

5.1 Article I: Change in TPACK beliefs and their connection with attitude toward simulations

5.1.1 Aims

In Article I, the aim was to study how the PSTs' beliefs on the different domains of the TPACK framework changed during the intervention. In addition, the aim was to study the possible connection between PSTs' TPACK beliefs in the different domains with their belief on the usefulness of simulations in science teaching and with their disposition toward integrating simulations into their teaching. These two constructs are seen as two domains of their attitude toward simulations, because they both reflect favourable or unfavourable feelings toward simulations (Fishbein & Ajzen 1975, Zacharia 2003).

5.1.2 Analysis of data

The instruments used are described in section 4.4. A one-sided (the change was assumed to be positive) t-test was used to determine the change in the PSTs' TPACK beliefs from the pre-test in week 1 of the intervention to the post-test in week 7 of the intervention. The alpha level was set at .05. Cohen's d was calculated to measure the size of the possible effect the intervention had on the PSTs' TPACK beliefs in the different domains. The connection between the PSTs' TPACK beliefs in the different domains and their views on the usefulness of simulations in science teaching and their disposition toward integrating simulations in their teaching was determined by calculating the Spearman's rank correlation coefficients (ρ) for the correlations between these scales. Spearman's rank correlation coefficients were chosen instead of, for example, Pearson's product-moment correlation coefficient (r), because the PSTs' views on the usefulness of simulations in science teaching and their disposition toward integrating simulations are measured using single Likert-scale items which are ordinal by nature (Carifio & Perla 2008). Some sources argue that analysis based on single Likert-scale items should be avoided (Carifio & Perla 2007), while others state that in some cases (for example, when there is a possibility of including items that are not proper synonyms of the concept under study) single-item measures can be used (Gardner et al. 1998, Wanous, Reichers & Hudy 1997).

5.1.3 Results

The results showed that the PSTs' beliefs in their CK, PK and TPACK were statistically significantly higher in the post-test than in the pre-test. Table 8 reports the results in more detail. The effect sizes calculated using Cohen's *d* show that the effect on CK beliefs was small, the effect on PK beliefs was medium and the effect on TPACK beliefs was large (Cohen 1988).

TABLE 8 The values from the pre- and post-tests for the domains of knowledge, paired sample one-sided t-test values, p-values and Cohen's d values

Domain of knowledge	Pre-test		Post-test		*t*-value	*p*-value	Cohen's *d*-value
	M	SD	M	SD			
CK	3.23	.90	3.65	.95	3.52	< .001	.45
PK	4.23	.78	4.85	.82	5.21	< .001	.77
TK	3.65	1.29	3.76	1.17	1.04	< .15	.09
TPACK	2.97	.81	4.20	.98	7.28	< .001	1.37

The Pearson's correlation coefficients between the PSTs' beliefs in the different domains in the pre- and post-tests (1-8) and the Spearman's rank correlation coefficients between the PSTs' beliefs in the different domains of the TPACK framework and their belief of the usefulness of simulations and their disposition toward integrating simulations into their teaching are reported in Table 9. The two different types of correlation coefficients are shown in the same table for reasons of clarity, and they are not meant to be compared with each other. The only domain in both the pre- and the post-test where the PSTs' beliefs statistically significantly correlated with their belief on the usefulness of simulations and their disposition toward integrating simulations in their teaching was the TK domain. The size of the correlation can be interpreted as a low positive correlation (Hinkle, Wiersma & Jurs 2003).

TABLE 9 Correlation coefficients for the domains of knowledge for both the pre- and post-tests for the PSTs' beliefs on the usefulness of simulations in and for their disposition toward integrating simulations

Area of study	1. [a]	2. [a]	3. [a]	4. [a]	5. [a]	6. [a]	7. [a]	8. [a]	9. [b]	10. [b]
1. CK – pre[a]	-									
2. PK – pre[a]	.43**	-								
3. TK - pre[a]	.16	.36*	-							
4. TPACK - pre[a]	.33*	.57**	.62*	-						
5. CK - post[a]	.69**	.35*	.19	.25	-					
6. PK - post[a]	.32*	.61**	.30	.23	.56**	-				
7. TK - post[a]	.16	.34*	.88**	.57**	.36*	.40*	-			
8. TPACK - post[a]	.28	.45*	.39*	.37*	.59**	.75**	.50**	-		
9. Usefulness[b]	.03	.08	.41*	.22	.-17	.-11	.39*	.09	-	
10. Integration[b]	.11	.17	.48**	.30	.00	.09	.44**	.19	.59**	-

Notes. ** $p < .01$. * $p < .05$ a = Pearson's r b = Spearman's ρ

5.1.4 Discussion

The results from Article I show that the intervention (see section 4.3) had a positive effect on the PSTs' beliefs about their CK, PK and TPACK (Table 9). The possible cause for this effect must be examined separately for each domain. As a part of the intervention, the PSTs had to revise the scientific content relating to the lesson they planned and implemented. This could explain the positive effect on CK beliefs. On the other hand, the items related to CK in the TPACK survey dealt with all areas of science, not just physics (which was the subject area in all of the implemented lessons). The effect on the intervention on the PK domain is interesting, because the items in the TPACK survey related to PK were not about PCK in science teaching but to general PK. The highest effect size was on beliefs related to the TPACK domain. As the objective of the intervention was to prepare PSTs to integrate an area of technology (simulations) into their science teaching in a pedagogically beneficial way (inquiry-based teaching), this result is very encouraging. The intervention increased the PSTs' beliefs in their ability to plan and implement science lessons in which technology is used in a meaningful way.

The intervention did not have an effect on the PSTs' beliefs about their TK, but at the same time their beliefs about their TK was the only domain of knowledge that statistically significantly correlated with their beliefs on the usefulness of simulations in science teaching and to their disposition toward integrating simulations into their science teaching. As developing general TK was not an objective of the intervention, the lack of an effect is not a surprise. The results show that the PSTs who had the strongest belief in their own TK were the ones with the most positive attitude toward simulations. This implicates that improving PSTs' belief about their own TK before they attend a course designed to familiarize themselves with simulations (such as the intervention presented in this dissertation) could improve their attitudes toward simulations as well.

These results also implicate that PSTs could have difficulties in discerning the domains of the TPACK framework from each other. The issue has been raised before, both generally relating to all teachers (Archambault & Barnett 2010, Brantley-Dias & Ertmer 2013) and especially relating to PSTs (Chai, Koh & Tsai 2010). Due to the lack of extensive teaching experience (at least teaching science), the PSTs belief in their general PK increased after planning and implementing one science lesson. It may be that they have difficulties discerning between their beliefs about science teaching PCK and general PK. The same issue may occur between the TK and TPACK domains. It might be easier for the PSTs to assess their beliefs about themselves as users of technology in general (belief in TK) compared to assessing their beliefs about their ability to plan and carry out science lessons in which technology is used appropriately (TPACK). The PSTs who participated in the intervention did not have much experience in teaching or learning science using technology. On the other hand, in their everyday life they encounter technology daily, and through these encounters they have a chance to form a conception of themselves as users of technology.

5.2 Article II: PSTs' beliefs on teaching science with simulations and the needed teacher know-how

5.2.1 Aims

The aim of Article II was to find out what sort of beliefs PSTs hold regarding teaching science with simulations. More precisely, the focus was on their beliefs about simulations' possibilities and weaknesses in science teaching and the PSTs' beliefs on the needed teacher know-how (closely linked with the conceptualization of teachers' practical knowledge (Van Driel, Beijaard & Verloop 2001)). Data were collected from two different universities (JYU and UO), so the final area of interest was whether the differences between the intervention at JYU and teaching experiment at UO could explain the possible differences in beliefs and teacher know-how between the PSTs from the two universities.

5.2.2 Analysis of data

The PSTs' answers regarding the possibilities of simulations in primary school science teaching (96 answers in JYU and 45 in OU) and the weaknesses of simulations in primary school science teaching (77 answers in JYU and 30 in UO) were analysed using thematic analysis (Braun & Clarke 2006). The answers were read multiple times, and initial codes were generated. These codes were used to form the themes which were in the end defined and named. For the analysis of the PSTs' answers regarding the teacher know-how needed to use simulations in science teaching (81 answers in JYU and 42 in UO) three predefined themes based on the TPACK framework were used—technological knowledge, pedagogical knowledge and content knowledge. The decision to the TPACK framework for the coding was the large amount of previous literature on the TPACK framework and teaching with technology. The domains of TPK, TCK, PCK and TPACK were not used in the coding in order to keep the frequencies in each categories somewhat high. To ensure reliability, two coders independently coded the data for teacher know-how. There was almost perfect agreement (Landis & Koch 1977) between the two coders, Cohen's $\kappa = .913$ (95% CI .851 to .976), $p < .001$. The differences were settled through negotiations. A chi-squared test was used to determine whether there was a difference between the observed distributions of the three types of teacher know-how between the PSTs from the two different universities and the expected distribution (similar to both universities). The alpha level was set at .05.

5.2.3 Results

Table 10 lists the themes identified in Article II regarding the PSTs' beliefs about the possibilities and weaknesses of using simulations to teach science. The themes are divided according to which of the two universities the PSTs' reported them in. Excerpts from each theme are provided in Article II.

TABLE 10 The identified themes for the PSTs' beliefs about the possibilities and weaknesses of simulations, their distributions between the two universities and their frequencies

Area of belief	Theme	University and frequency
Possibilities	Demonstrating different phenomena	JYU (34) and UO (15)
	Motivating the learners	JYU (14) and UO (9)
	Benefits for inquiry-based learning	JYU (15)
Weaknesses	Appropriateness of simulations for learning	JYU (7) and UO (11)
	The appearance of the simulations	JYU (15)
	Need for teacher support	JYU (8)
	Too few computers	JYU (7)
	Technical issues of simulations	UO (8)
	Effort of finding simulations	UO (5)
	Content issues of simulations	UO (5)

Table 11 lists the three domains of teacher know-how (CK, PK and TK) analysed from the PSTs' answers. Excerpts from each domain are provided in Article II. In JYU the most frequent theme was PK, and in UO the most frequent theme was TK. A chi-square test of independence was performed to examine the relation between intervention at JYU and the teaching experiment at UO and beliefs on teacher know-how. The relation between these variables was significant, χ^2 (2, N = 123) = 6.91, $p < .05$.

TABLE 11 Pre-service teachers' beliefs of the teacher know-how needed to teach with simulations

University		Content knowledge	Pedagogical knowledge	Technological knowledge
JYU (n = 81)	Frequency	17	39	25
	Percentage	21.0%	48.1%	30.9%
UO (n = 42)	Frequency	12	10	20
	Percentage	28.6%	23.8%	47.6%
JYU + UO	Frequency	29	49	45
(n = 123)	Percentage	23.6%	39.8%	36.6%

5.2.4 Discussion

The results show that the PSTs' beliefs about the possibilities of simulations (Table 10) at both universities were in line with current research on simulations. For example, the benefits of simulations in demonstrating otherwise unobservable phenomena have been highlighted (de Jong, Linn & Zacharia 2013), and the motivational benefits of simulations have been shown (Kiboss, Ndirangu & Wekesa 2004, Papastergiou 2009). As for the weaknesses of simulations (Table 10), the PSTs raised the issue that simulations are not always the appropriate tool to teach the specific content. Research results also back up this belief by stating that the best learning outcomes can be achieved by combining simulations with hands-on activities (Jaakkola & Nurmi 2008) and that conducting hands-on experiments can teach students about the underlying complexity of science—for example about measurement error (Windschitl 2000). The importance of teacher support has also been highlighted (Smetana & Bell 2012).

Some of the differences in beliefs between the two universities may be explained by the differences between the main intervention at JYU and the teaching experiment at UO. At JYU the lessons the PSTs implemented had to be inquiry-based, but at UO there was no such requirement. Thus, it comes as no surprise that the PSTs at JYU saw simulations' benefits for inquiry-based learning as one of their possibilities, while at UO the PSTs did not report this. At UO, the PSTs had to search for the simulations they used in the lessons they implemented. They also used the participating schools' devices to run the simulations. These factors might have caused some of them to form beliefs that the weaknesses of simulations include the effort required for finding them and the technical issues with using them in teaching. At JYU, these beliefs were not reported. The Interconnected Model of Teacher Professional Growth (Figure 3) (Clarke & Hollingsworth 2002) can be used to try to explain the difference. The intervention at JYU and teaching experiment at UO had some differences which caused the PSTs to receive different external stimuli, and reflecting on these stimuli has an effect on their beliefs. Also, because the technology used in the lessons which they implemented was different between JYU and UO, different beliefs were formed based on reflecting on those lessons and the consequences of those lessons on the students (salient outcomes).

These differences between JYU and UO might also be behind the statistically significant difference in the domains of teacher know-how needed to teach science with simulations the PSTs reported (Table 11). At UO, the most common domain of teacher know-how reported was the TK domain, while at JYU, the most common domain of teacher know-how reported was the PK domain. Again, using the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth 2002) to explain this finding, the difference in beliefs might have been caused by the different experiences (possible issues with technology) the PSTs had as part of their experimentation with teaching with simulations. Reflecting on these experiences affected their beliefs about simulations and teaching science with them.

5.3 Article III: Guidance provided by simulation and PSTs and the distribution of guidance

5.3.1 Aims

The aim in Article III was to classify the guidance (Lazonder & Harmsen 2016) provided by the Balancing Act simulation (University of Colorado Boulder 2017) (Figure 1, top left and Figure 5) and the PSTs in guiding the students who were using the simulation to investigate the phenomena of balance and torque. Also, the manifestation of the different patterns of distributed guidance (Tabak 2004) between the simulation and the PSTs was studied.

5.3.2 Analysis of data

The framework for different forms of guidance for inquiry-based learning by de Jong and Lazonder (2014) (Table 3) was used to classify the guidance provided by both the “Balancing Act” simulation (University of Colorado Boulder 2017) and the PSTs during the Investigation phase in two lessons implemented as a part of the intervention. Additionally, the analysis focused on how the different patterns of distributed guidance (Tabak 2004) (Table 4) manifested themselves when the PSTs guided the learners. The data came from two of the lessons implemented as a part of intervention. The lessons were taught to a third-grade class with 15 learners and a fifth-grade class with 13 learners. There was no significant difference in the level of content of the two lessons. The discussion (about 200 minutes) between the PSTs teaching with the Balancing Act simulation (n = 8) and the learners during the investigation phase of inquiry was transcribed.

To classify the guidance provided by the Balancing Act simulation, it was compared to a hypothetical, unguided version of the same simulation. In such a sandbox-like simulation, the students would be presented with just a seesaw and objects of varying weights to place on the seesaw; the simulation would provide no structure or feedback. This mirrors the same experiment conducted in a traditional, physical, hands-on method. The features found in the Balancing Act simulation and not the hypothetical, unguided version were scrutinized for their possible role in guiding the learners in their investigations. The term "guiding element" is used to describe the features of the simulation that guided the students. The guiding elements of the simulation were categorized into the typology for form of guidance by de Jong and Lazonder (2014).

The first phase of the analysis of the guidance provided by the PSTs dealt with discerning the guiding actions in different forms from the non-guiding actions. The descriptions of different forms of guidance by de Jong and Lazonder (2014) and examples from previous research on different forms of guidance by Zacharia et al. (2015) were used in the analysis. The length of these guiding actions ranged from single utterances to discussions lasting around three minutes. A total of 421 guiding actions were identified from the data. The second phase of the analysis used thematic analysis (Braun & Clarke 2006) to further classify the guidance provided by the PSTs that had the same form. The timing, content and possible connection to previous events of each guiding action were scrutinized when defining and naming the themes. To ensure reliability, another researcher coded parts of the data using a coding manual. Regarding discerning teachers' guiding actions from non-guiding actions, the second coder coded 10% of the data. The percentage of agreement between the authors was 96%, and $\kappa = 0.897$ (95% CI from .721 to 1), $p < .0005$. For the different forms of guidance, the second coder coded 15% of the data, and the percentage of agreement was 88%, and $\kappa = 0.798$ (95% CI from .675 to .904), $p < .0005$. These values indicate a fine reliability for this sort of high-inference coding (Fischer & Neumann 2012).

5.3.3 Results

The Balancing Act simulation is divided into three tabs: Intro, Balance Lab and Game. The Intro and the Balance Lab differ from each other by the complexity (number of objects and complexity of the ratio of weights and distances) of the situation the students have to balance the seesaw in. The Intro tab of the Balancing Act simulation is presented as a part of Figure 1. In the Game tab the students are asked to apply their knowledge in assignments of differing difficulty. Figure 6 shows an example assignment from the Game tab.

Table 12 shows the forms of guidance and guiding elements for inquiry-based learning provided by the Balancing Act simulation. The terms by Lazonder and Harmsen (2016) are used instead of those by de Jong and Lazonder (2014) as in the text of Article III. The changes are only textual and done merely to preserve coherence in the overview part of this dissertation.

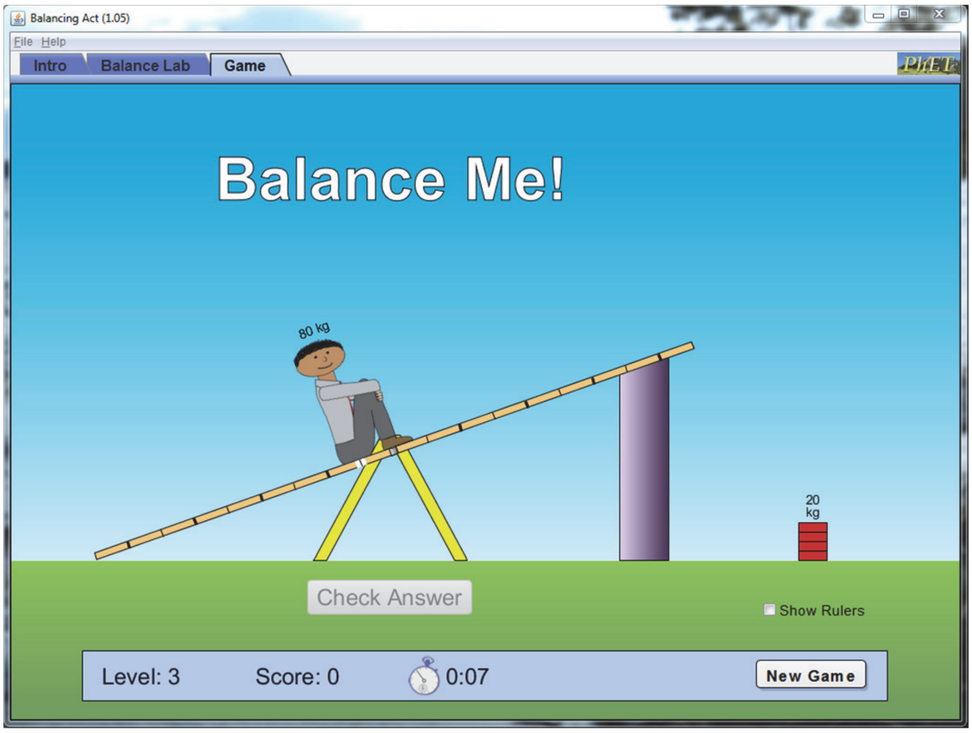


FIGURE 6 An example assignment from the Game tab of the Balancing Act simulation (University of Colorado Boulder 2017).

TABLE 12 Forms of guidance and guiding elements from the Balancing Act simulation with their descriptions

Form of guidance	Guiding element	Description
Process constraint	Progression within the simulation	Each subsequent tab enables more complex situations to be studied.
	Progression within the Game tab	Four different levels of assignments give students a chance to progress to more difficult assignments.
	Visualization settings	The distances of the objects from the fulcrum of the seesaw and the exerted forces are hidden by default but can be shown at will.
Status overview	Score	Points given in the Game tab give information to the students about their skills and knowledge.
Prompts	Assignments	Assignments in the Game tab prompt the learners to apply their skills and knowledge.
Explanation	Giving the correct answer	The correct answer to the assignments in the Game tab is shown after two wrong answers.

Table 13 shows the forms of guidance and guiding actions provided by the PSTs while they were guiding the students working with the Balancing Act simulation. The terms by Lazonder and Harmsen (2016) are also used here instead of those by de Jong and Lazonder (2014) as in the text of Article III. The changes are only textual.

An excerpt is presented as an example of the use of prompts to guide the learners. The excerpt below shows pre-service teacher B (PST B) prompting the learners to reflect on their actions after completing an assignment in the Game tab. In this assignment, the learners had to balance the seesaw using a weight of 20 kilos on one side with a fixed weight of 10 kilos on the far end of the other side.

> Student 5 [talking to Student 6, who is using the simulation]: So, put it there—no, wait, one step forward—that's it. Let's see if it's correct.
>
> [The 10-kilo weight is placed half as far from the fulcrum as the 20-kilo weight, but on the other side. The seesaw balances, and the simulation informs the learners of their correct answer.]
>
> PST B: Yeah.
>
> Student 5: It was.
>
> [Student 6 moves the mouse cursor to the "Next" button.]
>
> PST B: Don't go on to the next assignment yet—what was the reason that this was the correct answer? [Prompts – prompt for answer]
>
> Student 5: Well, wait a minute...
>
> Student 6: The 20-kilo weight is a bit heavier but…
>
> Student 7: Which means it's more to the centre.

In the excerpt, the students succeeded in balancing the seesaw and are ready to move on, indicated by them moving the cursor to the "Next" button. At this point, PST B prompts the learners to explain why their answer was correct. The discussion that follows was initiated by this prompt, and it probably would not have happened without it. The prompt served as a stimulus for the learners to reflect on their answer when they did not show initiative to do so on their own, which fits the description of prompts (Lazonder & Harmsen 2016).

TABLE 13 Forms of guidance and guiding actions provided by the PSTs with their descriptions

Form of guidance	Guiding action	Description
Process constraint	Reducing options	Suggestion to the students to e.g. use just two objects or hold an object in its place.
Status overview	Feedback on experimentation	Feedback for the students on e.g. good strategy for experimenting with the simulation.
	Feedback on answer	Feedback for the students after they have completed an assignment or have succeeded in an assignment given by the teacher.
Prompts	Prompt for action	Prompt to perform an action with the simulation e.g. to complete an assignment from the Game tab or to balance the seesaw in a given situation.
	Prompt for answer	Prompt to give a verbal response e.g. to set up a hypothesis or reflect on their actions.
Heuristics	Reminder	Reminder about a previous assignment or the rule which they can use to balance the seesaw.
	Hint	A hint to the students which gives them information needed to balance the seesaw or complete an assignment.
Scaffolds	Dividing the problem into smaller parts	Investigation into the similar ratios of weights and their distances from the fulcrum is structured by asking multiple simple closed questions in a row.
Explanations	Presentation of information	Presenting the students with e.g. the rule by which the seesaw can be balanced or the factors that affect the balance.

Table 14 presents examples of the three patterns of distributed guidance (Tabak 2004) which manifested in the lessons analysed in Article III.

TABLE 14 Examples of the patterns of distributed guidance (Tabak 2004) from the analysed lessons

Pattern of distributed guidance	Example
Differentiated guidance	Only the PSTs prompted to learners to reflect on their answers to the assignments provided by the simulations or on their learning in general.
Redundant guidance	The PSTs verbalized and paraphrased the assignments given by the simulation in the Game tab.
Synergistic guidance	The simulation provided different levels of assignments in the Game tab, and the PSTs instructed the students to either move on to a more difficult level or to stay at the same level.

An example scenario from the lessons where the guidance was redundantly distributed was when the teachers verbalized and paraphrased the assignments given by the simulation. This can be clarified through an excerpt. In the excerpt, the students are engaged with an assignment in the Game tab of the simulation.

In the assignment, the seesaw (see Figure 6) was shown in a pre-determined configuration with supports holding it in place. The instructions on the simulation read that the students had to determine what would happen to the seesaw (tilt to the left, tilt to the right, or remain horizontal) when the supports were removed. It is the first time during the lesson that the students encounter this type of an assignment.

> Student 1: So now…
>
> Student 2: This one has to be moved that way.
>
> Student 1: Yeah, this has to be moved this way in order to—
>
> PST A: That is true, but now—here, you don't have to move these, but if the situation is this: that 15 kilos is there and the other one is here, which of these options will happen? [Prompt – prompt for answer]

Even though the instructions for the assignment are written on the screen, the students seem to have difficulties understanding what they are expected to do in the assignment. In the excerpt, when the students encountered this type of assignment for the first time, at least two of them did not immediately understand that they could not move the weights on the seesaw and started to discuss where to move them. Some of the students in the group might have understood the assignment, but at least two did not. This caused the PST to verbalize the assignment, which transformed the written assignment into a verbal one, going from one mode of expression to another. This redundant guidance provided through different sources and modalities ensured that all members of the group received guidance in the form of a prompt (Tabak 2004).

5.3.4 Discussion

The results from Article III show (Table 12 and Table 13) how the PSTs provided more varied guidance than the Balancing Act simulation by providing all of the different forms of guidance (Lazonder & Harmsen 2016). The results also add to the methodology of studying guidance. The same typology of guidance by Lazonder and Harmsen could be used to classify the guidance provided by both the PSTs and the simulation. Regarding distributed guidance, the example manifestations (Table 14) of the three different patterns by Tabak (2004) have one characteristic in common: the PSTs were the guidance providers that enacted the patterns. The latter excerpt presented also highlights this. This emphasizes the important role that teachers play in guiding inquiry-based learning with simulations. Teachers' ability to adapt their guidance to both the needs of the learners and to the guidance provided by the simulation is crucial to enacting these patterns.

Adapting guidance to the needs of the learners is crucial, no matter if it is provided by teachers or simulations (de Jong & Lazonder 2014, Smetana & Bell 2012, van de Pol, Volman & Beishuizen 2010). Teachers can use questioning, especially probing questions (Sahin & Kulm 2008), to elicit students' knowledge and adapt their instruction (Lehtinen & Hähkiöniemi 2016). Other sources for obtaining information from the students include written evidence, graphic evidence, practical evidence (e.g. observing learners' work with a simulation) and non-verbal experience (e.g. body language) (Ruiz-Primo 2011). The conscious practice of discovering information about students' understanding and using this information to alter instruction is deeply related to the concept of formative assessment (Black 2009, Buck, Trauth-Nare & Kaftan 2010, Haug & Ødegaard 2015, Ruiz - Primo & Furtak 2007, Ruiz-Primo 2011), which has been argued to be one of the fundamental mechanisms for learning and for improving learning gains (Black & Wiliam 1998, Jordan & Putz 2004). Simulations cannot adapt to the students learning needs and knowledge to the same degree, because their ability to receive information about the students is limited. The assignments embedded within the Balancing Act simulation (Figure 6) highlight this. The only information the assignments use to give feedback to the students is when the student completes the assignment in his/her first, second or third attempt. Based on this, the simulation awards 2, 1 or 0 points and reveals the correct answer. This does not take into account the process of coming up with the answer; the simulation cannot take into account whether the student got the correct answer by guessing or through an elaborate process. The first presented excerpt highlights how the teacher can then elicit these explanations from the students. More complex software for science learning do exist which can obtain evidence from student outcomes from learning products inside the software (de Jong et al. 2010). The development of these sorts of software is still under way (de Jong & Lazonder 2014, Ferguson 2012, Olympiou & Zacharias 2013) and should be continued. Still, at the moment, teachers' ability to adapt their guidance to the students' needs is far beyond the ability of any software.

Teachers' guidance should also adapt to the guidance provided by the simulations. The patterns of distributed guidance (Tabak 2004) can be used to conceptualize the adaption of guidance provided by teachers to the guidance provided by the simulation. The pros and cons of each provider should be weighed against each other to design learning environments where guidance is provided by different sources—teachers, simulations or other learning material—and each source is utilized to the best of its ability. For example, teachers and simulations have different affordances for providing guidance: individual students or groups can interact with a simulation throughout a lesson and during all inquiry phases, while a teacher can only guide one group of students at a time or the entire class together. When the simulation provides some of the guidance (for example prompts in the form of assignments as in the Balancing Act simulation), the teacher can focus more on probing learners' needs and providing additional guidance (Lehtinen & Hähkiöniemi 2016), as evidenced by the excerpts. Further research is still needed as to which aspects of guidance can and should be delegated to the simulation and which aspects are best left to the teachers (van Joolingen, de Jong & Dimitrakopoulou 2007).

5.4 Article IV: The connection between forms of guidance and communicative approaches

5.4.1 Aims

The aim in Article IV was to study the possible link between forms of guidance provided by PSTs (Lazonder & Harmsen 2016) and the communicative approaches (CAs) (Mortimer & Scott 2003) they apply before and after the Investigation part of inquiry—that is, during whole class teaching. One particular lesson from the set of 8 lessons implemented during the intervention was chosen for closer study. The role of guidance in the "opening up" and "closing down" (Scott & Ametller 2007) the discussion that run throughout the lesson and how the provided guidance affected the pedagogical link-making processes (Scott, Mortimer & Ametller 2011) was specifically studied in Article IV.

5.4.2 Analysis of data

The analysis focused on the effect providing different forms of guidance by the PSTs has on the CAs they applied during different episodes in an inquiry-based science lesson. The different forms of guidance were defined using the framework by Lazonder and Harmsen (2016) (Table 3), which is based on the framework by de Jong and Lazonder (2014). The different communicative approaches were defined using the communicative approaches to classroom discourse by Mortimer and Scott (2003) (Table 6). A special focus was on "opening up" classroom discussions through dialogic and interactive talk and "closing down" these discussions using more authoritative talk (Scott & Ametller 2007). These "opening up" and "closing down" events usually take place before and after the investigation phase of inquiry (Lehesvuori et al. 2011) but are not restricted to this. One lesson implemented during the intervention was chosen for closer study based on the large amount of dialogic discourse in that particular lesson and the fact that it contained all the phases of inquiry by Pedaste et al. (2015) (Table 2). The topic of the lesson was static electricity, and the "Balloons and Static Electricity" (University of Colorado Boulder 2017) simulation was used to conduct part of the investigations alongside with hands-on materials. The lesson was implemented in a class of 15 sixth-graders.

The analysis took place as two parallel processes: one dealing with the forms of guidance provided by the PSTs and another dealing with the CAs. The forms of guidance provided by the PSTs were defined in Article IV by using the descriptions by Lazonder and Harmsen (2016) to identify PSTs' verbal actions that fit one of the descriptions. The analysis for the CAs began with defining episodes divided by a change in topic, a contrast in behaviour or a transition to the next type of conversation or activity (Jordan & Henderson 1995). A dominant CA was defined for each of the episodes using the definitions by Mortimer and Scott (2003) and paying attention to the fact that authoritative episodes could contain dialogic passages that still do not transform the episode into a dialogic one or vice versa. A communication graph (Lehesvuori et al. 2013) was constructed to visualize how the different CAs were applied during the lesson. Finally the analysis processes converged when the dominant CA was defined for each episode. This was done by analysing the role of each guiding action in forming the CA of each particular episode. The dominant form of guidance played the largest role in forming the CA. Reliability scores were not calculated due to the small amount of data and the case nature of the study, but researcher triangulation was conducted throughout the research process (Miles & Hubermann 1994), and the preliminary interpretations were presented and discussed with experts in classroom communication analysis.

5.4.3 Results

Figure 7 shows the communication graph from the lesson analysed in Article IV. The phases of inquiry, the communicative approaches applied per episode and the dominant forms of guidance for each episode are illustrated in the figure. Two excerpts from the lesson are analysed in full detail in Article IV.

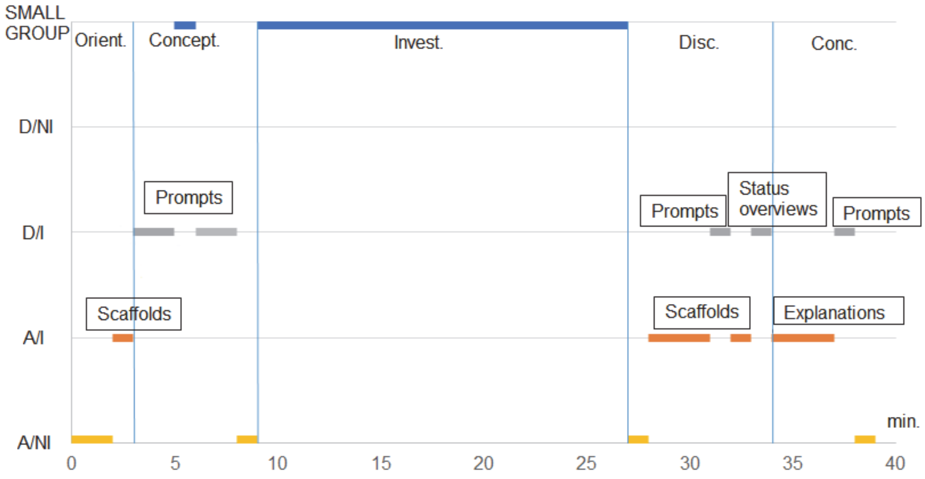


FIGURE 7 The phases of inquiry, the communicative approaches applied in the different episodes and the dominant forms of guidance for each episode in the lesson analysed in Article IV.

As shown in FIGURE 7, more non-specific forms of guidance (prompts and status overviews) were dominant in the episodes where the communication was dialogic and interactive. On the other hand, in the episodes where the communication was authoritative and interactive, more specific forms of guidance (scaffolds and explanations) were dominant. Article IV contains a detailed analysis of two excerpts, one from the "opening up" (Scott & Ametller 2007) part of the lesson (around minutes 3 to 8) from the inquiry phase of

Conceptualization (Pedaste et al. 2015) and another from the "closing down" part of the lesson (around minutes 34 to 38) from the inquiry phase of Conclusion.

During the first analysed excerpt (minutes 3 to 9) that dealt with "opening up" (Scott & Ametller 2007) the discussion, the PSTs orchestrated a whole group discussion about coming up with ideas regarding a teacher-led demonstration of static electricity, which started the lesson. The analysis showed how the PSTs used prompts to elicit the students' conceptions and existing ideas regarding static electricity. The PSTs also prompted the learners to come up with ideas in groups with their peers. The PSTs did not provide the students with explanations. Even though the ideas the students had about static electricity were not in unison with the scientific view of the phenomenon, the PSTs did not give out this information. They just acknowledged them without evaluation, which reduces the teachers' level of authority and gives more space to the students' own conceptions (Osborne 2010). The PSTs succeeded in "opening up" the discussion by prompting the students for their ideas, which enabled them to be worked with throughout the lesson. This together with not providing explanations as a response to these ideas enabled the communicative approach to be dialogic and interactive.

The second analysed excerpt (minutes 34 to 37) that dealt with "closing down" (Scott & Ametller 2007) the discussion continued throughout the lesson. During the excerpt, the PSTs are orchestrating a whole group discussion where the previously elicited students' ideas about static electricity are brought back in to the discussion after the students have had chance to investigate the phenomenon using a simulation and hands-on equipment. Similar to the first excerpt, multiple prompts are used to elicit students' conceptions on the ideas. Here, pedagogical link-making (Scott, Mortimer & Ametller 2011) promotes continuity and develops the scientific story by be referring explicitly to the students' ideas elicited during the Conceptualization phase of inquiry. This cumulative structure reflects the epistemic practices of inquiry (Furtak et al. 2012, Osborne 2010) and promotes learning about inquiry (Bybee 2000, Gyllenpalm, Wickman & Holmgren 2010).

The difference in prompting students' ideas in the second excerpt compared to the first one is that here the students' responses to these prompts are systematically followed by heuristics and explanations, which are specific forms of guidance (Lazonder & Harmsen 2016). The explanations and heuristics served as authoritative teacher turns. Even though sometimes the students' answers were not in conflict with the scientific view, by giving the explanations the PSTs ensured that all students were able to make the connection between the ideas collected in the first excerpt and the scientific view (Scott & Ametller 2007). These explanations serve as a pedagogical link (Scott, Mortimer & Ametller 2011) which promotes knowledge construction by differentiating between the scientific way of explaining with the everyday way of explaining and linking them with real world phenomena. Thus the discussion was "closed down", and the communicative approach was authoritative and interactive.

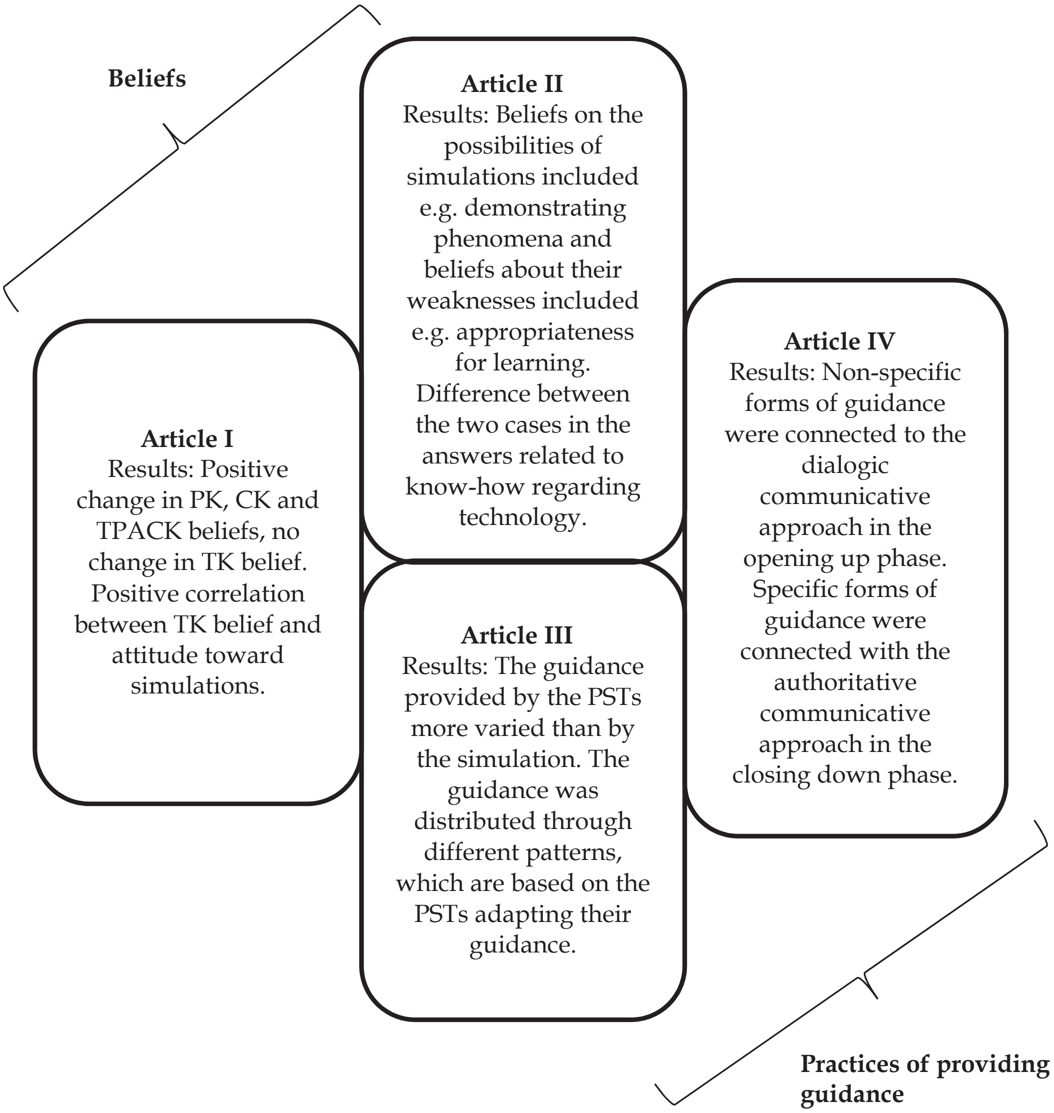
5.4.4 Discussion

The results from Article IV provide an example on how to plan and implement a lesson where simulations are used and that contain both a dialogic and interactive “opening up” part and an authoritative “closing down” part (Scott & Ametller 2007). Dialogic inquiry-based teaching that includes both a dialogic “opening up” part and a more authoritative “closing down” part has been described by a holistic model (Lehesvuori et al. 2011). This sort of model offers only limited possibilities for use in detailed lesson planning, which is seen as essential for implementing inquiry-based teaching in practice (Zubrowski 2007). In the lesson analysed in Article IV, the PSTs provided guidance in the form of prompts throughout the lesson (and thus eliciting their ideas and conceptions) and only provided more specific forms of guidance (such as scaffolds or explanations) after the students had had the chance to investigate their ideas. Thus, the discussion, which ran throughout the lesson, was opened up in the Conceptualization phase by examining the students’ ideas about static electricity dialogically and interactively. Only after these ideas were investigated in the Investigation phase did the PSTs provide the scientific view through explanations to the students. Thus, the discussion, which had run throughout the lesson, was closed down authoritatively. The structure of the lesson made it possible for the students to connect their own views and ideas with the scientific view. The PSTs linked the dialogic “opening up” and authoritative “closing down” phases of the lesson together through pedagogical link-making which connected the students pre-existing ideas with the findings from their investigations. Potentially, the results from Article IV that connect the somewhat concrete typology of the forms of guidance by Lazonder, and Harmsen (2016) with the more abstract typology of different CAs (Mortimer & Scott, 2003) could give teachers new ways to plan lessons with differing CAs.

The research on guidance for inquiry-based learning has concentrated on the effect that providing different forms of guidance for inquiry-based learning has on content learning outcomes (Alfieri et al. 2011, Lazonder & Harmsen 2016). The research on how guidance for inquiry-based learning can influence the acquisition of epistemic practices (see section 2.4) of science through inquiry has been called for (Hmelo-Silver, Duncan & Chinn 2007). The results from Article IV answer this call and add to the recommendations for guidance by Zacharia et al. (2015) who gave some recommendations based on a literature review on how different phases of inquiry-based learning should be guided by software to promote student learning in lessons where simulations are used to conduct the investigations. Their recommendations include providing scaffolds and prompts in the Conceptualization phase but did include providing explanations in the Conclusion phase. The findings from Article IV add to these recommendations in also looking at the guidance provided by teachers. If specific forms of guidance, such as scaffolds, are provided in the “opening up” part of the lesson (Conceptualization phase), the students are perhaps not able to elicit their ideas freely and conduct investigations based on them. Also, if explanations are provided in the “closing down” part (Conclusion phase), it could have positive effects on the students’ ability to connect their existing knowledge with the scientific view (Scott & Ametller 2007). As guiding inquiry-based learning is complex and should adapt to the needs of the students, recommendations that are always correct are difficult to give. Still, future research could delve into how software can provide guidance for inquiry-based learning that also promotes “opening up” and “closing down” the discussion during the inquiry processes.

5.5 Main results from the articles

Figure 8 sums up the main results from Articles I to IV.



Article I
Results: Positive change in PK, CK and TPACK beliefs, no change in TK belief. Positive correlation between TK belief and attitude toward simulations.

Article II
Results: Beliefs on the possibilities of simulations included e.g. demonstrating phenomena and beliefs about their weaknesses included e.g. appropriateness for learning. Difference between the two cases in the answers related to know-how regarding technology.

Article III
Results: The guidance provided by the PSTs more varied than by the simulation. The guidance was distributed through different patterns, which are based on the PSTs adapting their guidance.

Article IV
Results: Non-specific forms of guidance were connected to the dialogic communicative approach in the opening up phase. Specific forms of guidance were connected with the authoritative communicative approach in the closing down phase.

FIGURE 8 The main results from Articles I to IV.

6 CONCLUSIONS

6.1 Conclusions regarding Articles I and II

Together, Articles I and II address the first research question of this dissertation: *"What are PSTs' beliefs on teaching science with simulations, and what is the connection between their beliefs on their TPACK to their attitudes toward simulations?"*. The results from Article I show that the PSTs' with the highest beliefs about their own TK before and after the intervention had the most positive attitude toward using simulations in science teaching. Similar results using different theoretical frameworks have been achieved. Kriek and Stols (2010) reported that with South African in-service teachers their self-assessed general technology proficiency predicted their use of simulations to teach science. More generally, Chen (2010a) reported that with American PSTs' their perceived self-efficacy (which is deeply connected with PST' beliefs about themselves as users of technology) was positively connected with their use of technology in teaching.

This result from Article I is reinforced by the research on achievement motivation and behaviour. The widely used (Gorges & Kandler 2012, e.g. Wigfield & Eccles 2000) expectancy-value model of achievement originally by Eccles (1983) states that self-concept of one's abilities and sense of utility is related to achievement-related choice. The results from Article I show a correlation between the PSTs' beliefs about their TK (self-concept of abilities) and both their beliefs on the usefulness of simulations (sense of utility) and their dispositions toward integrating simulations into their teaching (achievement-related choice). The novelty of this result from Article I lies in the fact that it connects the multitude of research on PSTs' TPACK to their attitudes toward a specific form of educational technology.

Article II shows that after taking part in an intervention or teaching experiment as described in this dissertation, PSTs hold beliefs that are in unison with the current research on teaching and learning science with simulations. The results also show the role that designing a module (intervention or teaching experiment) for PSTs can play in regard to their beliefs on the topic. The assumption can be made that because the PSTs at UO did not have a chance to test the devices on which they had planned to run the simulations before the implementing the lesson, some of them had technical difficulties with running them. Through reflecting on this experience, they formed a belief that one of the weakness of simulations is their technical issues. They also had to search for the simulations to use in their lessons. Reflecting on this experience caused them to form a belief that one of the weakness of simulations is the effort in finding them. It can also be assumed that the PSTs at UO answered that to teach science with simulations, teachers need to have more TK due to these experiences of dealing with technical issues. The same connection is possible between the belief that the PSTs from JYU held that one of the weakness of simulations is the need for teacher support and in their answers highlighting the role of PK in teaching with simulations.

The main results regarding the first research question of this dissertation—*"What are PSTs' beliefs on teaching science with simulations, and what is the connection between their beliefs on their TPACK to their attitudes toward simulations?"*—can be summed up as follows:

- Pre-service teachers' belief in their own technological knowledge is connected with their attitude toward simulations in teaching (Article I).

- After the intervention and teaching experiment described in this dissertation, the pre-service teachers' beliefs about simulations are such that they can be backed up by empirical research results (Article II).

- The content of such an intervention had an effect on the beliefs the pre-service teachers hold after it (Article II).

6.2 Conclusions regarding Articles III and IV

Together, Articles III and IV address the second research question of this dissertation: *"How do different aspects of guidance for inquiry-based learning with simulations manifest in the pre-service teachers' practices?"*. These different aspects are recognized as the distribution of guidance between the PSTs and the simulation (Article III) and how guidance in different forms can affect possibilities for meaningful science learning (Article IV). The proper distribution of guidance is important to ensure that inquiry-based learning is guided in a way that maximizes the benefit that each provider of guidance can offer. Article III highlighted how the guidance provided by PSTs was more varied (more forms of guidance) than the guidance provided by the Balancing Act simulation and the importance of the teacher in enacting the different patterns of distributed guidance. The matter of providing guidance not just to benefit learning scientific content (for example, conceptual knowledge) and also how to argue for or against your ideas and to provide meaningful connections between students' views and the scientific view are in need of research. Article

IV demonstrated how providing only non-specific forms of guidance enabled the PSTs to open up the lesson dialogically. More specific forms of guidance were provided after the investigations to close down the lesson authoritatively. This sort of cumulative structure including pedagogical link-making (Scott, Mortimer & Ametller 2011) promotes making connections between the students' own ideas and the scientific view.

The main results regarding the second research question of this dissertation—*"How do different aspects of guidance for inquiry-based learning with simulations manifest in the pre-service teachers' practices?"*—can be summed up as follows:

- The pre-service teachers provided more varied guidance for the investigations with the simulations than the simulation itself (Article III).
- The pre-service teachers are able to adapt their guidance to the guidance provided by the simulation (Article III).
- Meaningful science lessons could benefit from providing prompts throughout the lessons and more specific forms of guidance only after the Investigation phase (Article IV).

6.3 Implications regarding teacher training

The broader aim of this dissertation was to give guidelines to improve teacher training related to teaching science with simulations. Here, two different lines of thought should be discerned from each other—the first dealing with how to encourage PSTs to start using simulations in their teaching and the other dealing with promoting good quality instruction with simulations. Guided inquiry-based learning can be seen as one beneficial instructional strategy.

Previous research has argued that to promote the use of technology in science teaching, PSTs should be exposed to different pedagogical uses of technology during their science methods courses (Maeng et al. 2013, Zacharia, Rotaska & Hovardas 2011). Here attention should be paid to the PSTs' still developing TPACK. Kontkanen et al. (2014) use the term "proto-TPK" to describe the evolving nature of content-free TPK consisting of previous experiences with technology and previous pedagogical experiences. During pre-service teacher training, this proto-TPK could develop into professionally mature TPACK through associating it with new technological, pedagogical and content experiences. A module such as the intervention reported in this dissertation could serve as an example of such exposure to these three areas.

When talking about preparing PSTs to use simulations in particular, science methods courses should also introduce other means of investigation, such as traditional hands-on activities, to the PSTs participating in such courses. In some cases, the best learning outcomes have been achieved by combining simulations with hands-on activities (Jaakkola & Nurmi 2008). Concerns have also been raised that simulations do not convey the complexity of doing science

(Windschitl 2000). Physicality, meaning the actual and active touch of concrete material and apparatus, has also been argued to be important for learning for younger learners who lack previous knowledge about the phenomena under study (Zacharia, Loizou & Papaevripidou 2012).

As the results from Article I show, there is a low positive correlation between the PSTs' belief in their own TK and their attitude toward simulations. As described in Chapter 1, teachers' attitude toward technology predicts their usage of it in teaching (Teo, Lee & Chai 2008, Teo 2009, Zacharia 2003). This implicates that attention should be paid throughout pre-service teacher training to increasing the PSTs' belief in their own TK. Based on the results of Article I, the PSTs' whose belief in their TK is high when coming into a course designed to promote the use of simulations have a more positive attitude towards the use of simulations after the course. Integrating technology into different pedagogical and content studies during teacher training (Valtonen et al. 2011) is one possible way to increase PSTs belief in their own TK. Having a "basic level" of belief in one's own TK could prepare the PSTs to start experimenting with using technology to teach different subjects.

Based on the results from Article II, attention should be paid to the amount of support the PSTs are given as a part of teacher training modules aimed at promoting the use of simulations in science teaching. Ideally, after going through teacher training, the just-graduated teachers would have a realistic view of what working as a teacher entails. As for using simulations to teach science, this work includes selecting simulations suitable for the content and skills to be taught. In addition, even though using simulations does not require much technological skill, with technology there is always the possibility for something to go wrong. The browser can crash or is not compatible with the simulation or you need a PC to run them instead of a tablet. Dealing with these sorts of matters as a part of the process of planning and implementing lessons during pre-service teacher training might shift the PSTs' focus away from the pedagogy of using simulations to the possible technological issues. The results of Article II show that the PSTs at JYU and UO had some differences in their beliefs about simulations after teaching with them for the first time. Some of these differences seemed to reflect the different contexts the lessons were implemented in. Attention needs to be paid to providing adaptive support to the PSTs as a part of planning and implementing the lessons. This support should be faded away throughout pre-service teacher training (Kim et al. 2013). The PSTs need to be able to believe in their own TK and that they are capable of dealing with any possible technological issues that may appear. Then they can concentrate more on the actual teaching with the simulations; this process can be supported by, for example, feedback from peers and teacher educators, as was done in the intervention presented in this dissertation.

To prepare PSTs to teach science effectively with simulations, these efficient and research-based strategies need to be introduced to them. Properly guided inquiry-based learning is this sort of strategy based on current knowledge (de Jong & Lazonder 2014, Furtak et al. 2012, Rutten, van der Veen

& van Joolingen 2015, van Joolingen, de Jong & Dimitrakopoulou 2007). Planning and implementing lessons based on, for example, the 5E learning cycle model (Bybee et al. 2006) or the model by Pedaste et al. (2015) (Table I) give guidelines for the PSTs on how the different activities (for example, hypothesis generation and investigation) that are part of inquiry-based learning are connected with each other. As PSTs' conceptions of inquiry are lacking without any training (García-Carmona, Criado & Cruz-Guzmán 2017, Lehesvuori et al. 2011), they need to be supported in planning and implementing inquiry-based lessons, regardless of whether simulations or hands-on equipment are used. In the intervention reported in this dissertation, the PSTs received feedback on their lesson plans from their peers and teacher educators. The teacher educators also provided feedback to the groups on their lessons after they had implemented them. This feedback can function as an external stimulus, which then can be reflected on through a process mediated by the PSTs' existing beliefs (Clarke & Hollingsworth 2002).

As guidance for inquiry-based learning and different communicative approaches applied during inquiry-based learning are both deemed important for the successful implementation of inquiry-based learning (Blanchard et al. 2010, Lazonder & Harmsen 2016), these two concepts could be introduced and reflected upon during pre-service teacher training. Previous studies (Lehesvuori, Viiri & Scott 2009, Lehesvuori, Viiri & Rasku-Puttonen 2011, Lehesvuori et al. 2011) on introducing dialogic teaching and the concept of communicative approaches to pre-service teachers could serve a basis for this. PSTs see providing guidance to the students as an issue and difficulty, as evidenced in the results from Article II (Table 10) and earlier research (Yoon, Joung & Kim 2012). As argued for in sections 2.3 and 2.4 and in Article IV, the issues of guiding inquiry-based learning by different forms of guidance and applying different communicative approaches are connected. Guidance (or scaffolding) can be seen not as a "tool-for-result" but also as a "tool-as-result" (Askew 2007, Bakker, Smit & Wegerif 2015). This means that guidance is not a separate part of teaching, which can be inserted or removed to achieve a given learning goal, but instead it is seen as something that cannot be separated from the other parts of teaching. Through dialogic and interactive teaching—which is promoted through providing prompts and not providing specific forms of guidance—the students are able to explore the epistemic practices of science: there exist multiple views of natural phenomena, which are developed through scientific experimentation into the prevailing scientific view. Still, there is a need for more authoritative teaching—which is promoted through providing specific forms of guidance—through which the prevailing scientific view is isolated and clarified. The holistic model of dialogic inquiry-based teaching containing the "opening up" and "closing down" parts by Lehesvuori et al. (2011) can be augmented with the different forms of guidance that promote the application of different communicative approaches.

As guidance for inquiry-based learning can be offered through multiple sources—including the teacher, the possible simulation environment and the accompanying learning material—teachers need to be aware of the affordances each provider of guidance has. The system of multiple providers of guidance can be seen as a learning environment (Tabak 2004), and, as the findings of Article III show (section 5.3.4), the teacher has the responsibility of designing guidance in a way that promotes learning. This requires the teacher to be aware of which of the students' needs are best supported through which source of guidance (Tabak 2004, van Joolingen, de Jong & Dimitrakopoulou 2007). Teachers can be seen as the designers of these learning environments containing multiple sources of guidance (Kim, Hannafin & Bryan 2007, Vosniadou et al. 2001). As simulations have become increasingly more widely used in teaching (as evidenced by the TIMSS results discussed in Chapter 1), teachers need to be trained to have skills to design these learning environments where simulations are used. As teachers' conceptions of a good learning environment depend on their conceptions of learning and teaching (Könings, Brand - Gruwel & Merriënboer 2005), this matter comes back to preparing PSTs to plan and implement guided inquiry-based lessons. As the PSTs are able to form beliefs that they are able to implement guided inquiry-based lessons that are beneficial for learning, their conception of teaching and learning should reflect this belief. This conception then has an effect on which sorts of learning environments containing guidance for inquiry-based learning they design. As the issue of which source of guidance is best to support each of the students' needs is still in need of further study (van Joolingen, de Jong & Dimitrakopoulou 2007), training PSTs to design learning environments in which each provider of guidance is used to their full potential and synergistically is an ambitious goal to strive for. With this matter, and all other matters presented in this chapter, pre-service teacher training is probably not enough to have a lasting impact. In-service teacher training is also necessary.

Concisely, here are implications discussed in this chapter to improve teacher training related to teaching science with simulations:

- The use of simulations should be presented during pre-service teacher training as one possible way of conducting the investigations that are essential to inquiry-based learning. The intervention presented in this thesis is an example of this.
- Pre-service teachers' beliefs in their technological knowledge should be developed throughout their teacher training.
- The amount of support the pre-service teachers are given during their studies on inquiry-based science teaching with simulations should be carefully balanced.
- The different communicative approaches and different forms of guidance could be introduced together during pre-service teacher training.
- Pre-service teachers should recognize the possibilities of different providers of guidance in order to design learning environments in which each provider of guidance is used to their full potential.

6.4 Future research

The implications presented in the previous section could be studied in the future. This could be done by planning and implementing a longer intervention aimed at improving PSTs' skills in designing learning environments that provide guidance for inquiry-based learning from multiple sources. By closely following the learning process the PSTs go through during this intervention (through observations and possibly interviews), the crucial aspects of the intervention could be determined. Here, the paradigm of design-based research (Wang & Hannafin 2005) could be used. Through iterative analysis, design and implementation, design-based studies produce design principles and theories that are contextually sensitive. Design-based research has recently been used to study pre-service teacher training on inquiry-based science teaching utilizing different communicative approaches (Ratinen 2016).

Outside of studying teacher training, the optimal distribution of guidance between different providers for inquiry-based learning is still in need of research (Ustunel & Tokel 2017, van Joolingen, de Jong & Dimitrakopoulou 2007). More studies need to be conducted on what forms of guidance are best suited to be provided by the software (for example, simulations) and how the teacher can provide guidance that synergizes with this. The results from Article III just described the manifestations of the different patterns of distributed guidance, but future research should move toward studying how, for example, the synergistic pattern of distributed guidance can be promoted.

The results from Article IV showcased an example of how the PSTs provided guidance to "open up" the lesson and at the same time applied a dialogic approach to the classroom communication. The simulation used to conduct the investigations on that lesson did not directly play a part in providing this "dialogic guidance". Current research on the possibilities of technology to support dialogic learning (Wegerif & Mansour 2010, Wegerif 2010) could be used as a basis for future research that could delve into how to provide guidance for inquiry-based learning via software (for example, simulations). Here, for example, the IDRF-pattern of talk (Wegerif & Scrimshaw 1997) could be beneficial to promote the dialogic construction of meaning by adding peer discussions (the D in IDRF) to the otherwise authoritative IRF-pattern (Lemke 1990) of talk (see section 2.4). As in the lesson analysed in Article IV, when the students are prompted to give their hypotheses or preliminary ideas on the phenomenon under study and when these ideas are being brought into the whole group discussion, this promotes the shared construction of knowledge. Modern communication technology also provides new opportunities for dialogue. Students could see and work with ideas or hypotheses from students who have been working on the same topic from somewhere else in the world. This could promote the learning of epistemic practices of science through engaging in a form of dialogue not just with students in the same classroom but also from students from other continents.

7 LIMITATIONS AND ETHICAL ASPECTS

In keeping with ethical requirements, written permission to collect and use data for research purposes was obtained from all voluntary participants. In addition, participants had the right to withdraw at any point without further obligation or to participate partially (British Educational Research Association 2011). For example, if a PST did not wish to be video recorded or complete the other study instruments, he/she could still take part in other activities executed within the intervention. The same was done for students in the implemented lessons; those students whose guardians did not give permission to the study or did not return the permission sheet were excluded from the video recordings. Pseudonyms were used in publications in order to preserve the anonymity of the participants. The data was kept in a secure location.

As the author of this dissertation was also one of the teacher educators who planned and executed the intervention in JYU, objectivity of the research must also be examined. Researcher triangulation was used throughout the dissertation process to minimise bias and to ensure the trustworthiness of the interpretations (Miles & Hubermann 1994). The aim of the intervention was not teach the PSTs any "new" or "better" beliefs (from a research point of view). The intervention was planned according to contemporary research results regarding inquiry-based learning with simulations. The intervention was executed as a part of the science methods course to the PSTs. The content of the intervention was designed so that it would fill the learning goals set to the whole methods course. Different groups have had different contents for this science methods course based on on-going research or projects, but the learning goals always have stayed the same. In addition, the implemented lessons in the primary schools followed the Finnish national core curriculum and the topics were chosen together with the teachers of the participating classes. This was done to ensure that the students' learning would not be harmed from participating in the study.

As the study instruments and implemented lessons were in Finnish, but this dissertation and the included articles are in English, the issue of language should also be examined. The transcriptions of the lessons and the excerpts presented in the articles were done by the author of this dissertation. The results were presented in international conferences and summer schools where also native speakers could give their feedback on the conclusions. The results were also published in international journals and the reviews did not mention issues regarding conclusions made from the transcripts. Thus, the issue of cultural differences in communication was given some consideration (Nikander 2008).

As for the limitations of the study, the quite small number of participants in Articles I and II should be noted. Still, they represent about 25% of the annual intake for primary PSTs in JYU and UO and the age and gender distribution were typical for primary teacher education in Finland. In addition, the PSTs in JYU were all majoring in special education. Even though this fact can their perceptions and beliefs, in Finnish primary schools many of them will be employed as primary teachers and not special education teachers and the content of their subject studies (including natural sciences) is similar to the students majoring in primary teacher studies. The results from these articles can be seen as representing the cohort group of the PST population of the two universities but may not be generalizable across all contexts and populations.

In retrospect, Article I would have benefited from using a previously validated TPACK survey, for example the survey by Lin et al. (2013) in its aoriginal form. The end survey (Appendix II) could have also contained multiple Likert items to measure PSTs attitudes toward simulations. This would have increased the statistical power of the results. The questionnaire by Zacharia, Rotsaka and Hovardas (2011) that investigates teachers' beliefs, attitudes, and intentions concerning the use of simulations for educational purposes could also have been used to study the same concepts as in Articles I and II. Article I would also have benefited from using a control group alongside the intervention group. The lack of a control group was caused by the change in the curriculum at the Department of Teacher Education at the University Of Jyväskylä during the time of the data collection. The intervention group were the last PSTs still studying with the old curriculum. Thus, a comparable control group was not available. Also, as the surveys can only measure self-assessed knowledge, other means to measure TPACK such as analyzing the performance of the PSTs as they complete different tasks (Koehler, Shin & Mishra 2012) could have allowed the triangulation of their knowledge from different data sources.

The static group comparison design (Gall, Gall & Borg 2007, p. 402) (lack of pre-test of beliefs for the PSTs in JYU and UO) can be seen as a weakness of Article II. However, because the PSTs did not have experience on learning or teaching science with simulations before the intervention in JYU and the teaching experiment in UO, it is reasonable to assume that their beliefs were mainly formed based on their experiences in these two modules. In addition, Articles III and IV are based on cases (2 lessons for Article II and 1 lesson for Article IV) related to teaching a certain topic using a certain simulation. The focus of those articles is in describing the guidance for inquiry-based in those contexts' and not in describing this guidance throughout all other contexts' as well. In Articles II and IV, the PSTs taught the lesson in small groups. This differs from normal lessons where the teacher teaches alone.

YHTEENVETO

Tietokonesimulaatiot ovat ohjelmia, jotka mallintavat todellisen maailman ilmiöitä esimerkiksi tietokoneen tai tabletin ruudulla. Simulaatioiden avulla voidaan tutkia erilaisia ilmiöitä niin monta kertaa kuin halutaan ja tarkastella erilaisten lähtöarvojen vaikutusta lopputulokseen. Simulaatiot mahdollistavat myös sellaisten ilmiöiden tutkimisen, joita olisi muuten luokkahuoneessa mahdoton tutkia joko suuren tai pienen kokonsa tai nopeutensa takia. Niiden avulla voidaan havainnollistaa esimerkiksi elektronien liikettä sähköjohtimissa. Simulaatioiden käytöllä osana luonnontieteiden opetusta on tutkittuja etuja muihin opetusmuotoihin nähden sekä käsitteellisen osaamisen että oppimismotivaation alueilla. Erityisen hyvin simulaatiot sopivat käytettäviksi osana tuettua tutkivaa oppimista.

Kansainvälisessä TIMSS 2015 -tutkimuksessa on todettu, että verrattuna muihin maihin suomalaiset neljäsluokkalaiset pitävät luonnontieteiden opiskelusta kaikkein vähiten. Simulaatiot tarjoavat mahdollisuuden luonnontieteiden oppimismotivaation lisäämiseen, mutta niitä käytetään suomalaisilla neljännen luokan luonnontieteiden oppitunneilla kansainvälistä keskiarvoa vähemmän. Luokanopettajien peruskoulutuksella on suuri rooli simulaatioiden käyttöönotossa alakoulun luonnontieteiden opetuksessa, koska suomalaiset opettajat eivät juuri osallistu tieto- ja viestintäteknologian (TVT:n) käyttöä luonnontieteen opetuksessa koskeviin täydennyskoulutuksiin. Opettajien ja opettajaopiskelijoiden tieto- ja viestintäteknologiaan liittyviin asenteisiin ja uskomuksiin tulee kiinnittää huomiota, sillä ne vaikuttavat merkittävästi teknologioiden käyttöönottoon opetuksessa. Pelkkä TVT:n ja simulaatioiden käyttöönotto ei kuitenkaan riitä, vaan opettajien ja opettajaopiskelijoiden on saatava valmiudet laadukkaaseen simulaatioiden avulla tapahtuvaan opetukseen.

Tämä väitöskirja koostuu neljästä kansainvälisissä lehdissä ja konferenssijulkaisussa julkaistusta artikkelista sekä teorian, metodit ja tulokset kokoavasta yhteenveto-osuudesta. Tutkimuksen keskiössä olivat luokanopettajaopiskelijoiden asenteet ja uskomukset simulaatioiden käyttöön liittyen sekä heidän opetuskäytänteensä, kun he ohjasivat tuettua tutkivaa oppimista simulaatioiden avulla. Opetuskäytänteistä tarkasteltiin erityisesti tuen hajauttamista opettajan ja simulaation välillä sekä annetun tuen vaikutusta luonnontieteiden merkitykselliseen oppimiseen ja luokkahuonevuorovaikutukseen.

Päätutkimuskohteena olivat luokanopettajaopiskelijat (n = 40), joka osallistuivat simulaatioiden laadukkaan opetuskäytön edistämiseen suunniteltuun interventioon Jyväskylän yliopiston opettajankoulutuslaitoksella syksyllä 2014. Heiltä kerättiin kyselydataa, joka liittyi heidän uskomuksiinsa omasta teknologis-pedagogisesta sisältötiedostaan sekä heidän uskomuksiinsa ja asenteisiinsa simulaatioihin liittyen. Opettajaopiskelijat myös suunnittelivat ja toteuttivat tutkivaan oppimiseen pohjautuvia oppitunteja osana interventiota. Nämä oppitunnit videoitiin ja toiminta simulaatioiden parissa tallennettiin ruudunkaappausohjelmistolla. Vastaava kyselydata uskomuksista kerättiin myös Oulun yliopiston luokanopettajaopiskelijoilta (n = 18), jotka osallistuivat samankaltaiseen opetuskokeiluun.

Tulokset osoittavat, että luokanopettajaopiskelijoiden uskomukset heidän omasta teknologisesta tiedostaan olivat yhteydessä heidän asenteisiinsa simulaatioiden käyttöä kohtaan. Nämä uskomukset eivät muuttuneet intervention aikana. Luokanopettajaopiskelijoiden uskomukset simulaatioiden avulla tapahtuvan opetuksen mahdollisuuksista ja heikkouksista vastasivat melko hyvin aiemmissa tutkimuksissa tehtyjä havaintoja simulaatioiden mahdollisuuksista ja heikkouksista. Eri yliopistojen opettajaopiskelijoiden simulaatioihin liittyvissä uskomuksissa havaittiin kuitenkin eroja, jotka voidaan yhdistää intervention ja opetuskokeilun eroihin.

Tuetun tutkivan oppimisen käytänteitä tutkittiin esimerkkioppituntien videoinneista. Tulokset osoittavat, että opettajan antamalla tuella on tärkeä merkitys simulaatioiden opetuskäytössä. Opettajaopiskelijat pystyivät mukauttamaan antamaansa tukea sekä oppilaiden toiminnan että simulaation antaman tuen mukaan. Heidän antamansa tuki oli myös monipuolisempaa kuin simulaation antama. Annetun tuen tarkkuudella oli vaikutusta luokkahuonevuorovaikutuksen luonteeseen. Avoimemmat tukimuodot edistivät jo olemassa olevan tiedon esille tuontia ja jakamista, kun taas suljetumpia tukimuotoja käytettiin luomaan linkkejä uuden tiedon ja arkipäivän ilmiöiden välille sekä vahvistamaan tieteellistä näkökulmaa tarkasteltavaan ilmiöön.

Tutkimuksen johtopäätökset ovat kaksitahoiset. Ensinnäkin opettajaopiskelijoiden uskomuksia omaan teknologiseen tietoonsa tulisi vahvistaa koko opettajaopintojen ajan. Samalla heille tulisi tarjota mahdollisuuksia tutustua erilaisten opetuksessa käytettävien TVT-sovellusten, kuten simulaatioiden, käyttöön ohjatusti opinnoissaan. Opiskelijoita olisi hyvä ohjata simulaatio-opetuksessa siten, että yhtäältä heille annettaisiin realistinen kuva teknologian käytön haasteista ja toisaalta he saisivat tuetusti keskittyä pedagogiikan harjoitteluun.

Toiseksi opettajaopiskelijoille voitaisiin esitellä tuetun tutkivan oppimisen mallin yhteydessä siihen liittyvät tuen eri muodot sekä näiden tukimuotojen merkitys luokkahuonevuorovaikutukselle. Heidän tulisi tunnistaa erilaisten tuen lähteiden, kuten opettajan ja simulaation, mahdollisuudet ja rajoitteet tuen antamisessa, jotta he voisivat suunnitella tuettuun tutkivaan oppimiseen liittyviä oppimisympäristöjä. Tämän prosessin kautta he saisivat valmiuksia mukauttaa tarjoamaansa tukea muiden lähteiden tukeen.

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APPENDICES

APPENDIX 1 – The TPACK survey

The answers for all the items are given using a seven-point Likert scale (1 = I disagree strongly, 7 = I agree strongly), L = (Lin et al., 2013), Z = (Zelkowski et al., 2013).

CK1: I have sufficient knowledge of science to teach science. L
CK2: I can think about the content of science like a subject matter expert. L
CK3: I have various strategies for developing my understanding of science. Z
CK4: I have a deep and wide understanding of biology. Z
CK5: I have a deep and wide understanding of physics. Z
CK6: I have a deep and wide understanding of geography. Z
CK7: I have a deep and wide understanding of chemistry. Z
PK1: I am able to stretch my students' thinking by creating challenging tasks for them. L
PK2: I am able to guide my students to adopt appropriate learning strategies. L
PK3: I am able to help my students to monitor their own learning. L
PK4: I am familiar with common student understandings and misconceptions. Z
PK5: I know when it is appropriate to use a variety of teaching approaches (e.g., problem/project- based learning, inquiry learning, collaborative learning, direct instruction) in a classroom setting. Z
PK6: I know how to assess student performance in a classroom. Z
PK7:.I can assess student learning in multiple ways. Z
PK8: I can adapt my teaching based upon what students currently understand or do not understand. Z
TK1: I have the technical skills to use technology effectively. L
TK2: I can learn technology easily. L
TK3: I know how to solve my own technical problems when using technology. L
TK4: I keep up with important new technologies. L
TK5: I have had sufficient opportunities to work with different technologies. Z
TK6: I frequently play around with the technology. Z
TK7: I know a lot about different technologies. Z
TK8: When I encounter a problem using technology, I seek outside help. Z (negatively phrased)
TPACK1: I can teach lessons that appropriately combine biology, technologies, and teaching approaches. Z
TPACK2: I can teach lessons that appropriately combine physics, technologies, and teaching approaches. Z
TPACK3: I can teach lessons that appropriately combine geography, technologies, and teaching approaches. Z
TPACK4: I can teach lessons that appropriately combine chemistry, technologies, and teaching approaches. Z

TPACK5: I can provide leadership in helping others to coordinate the use of science, technologies, and teaching approaches in my school and/or district. L
TPACK6: Integrating technology with teaching science will be easy and straightforward for me. Z

APPENDIX 2 – The end survey

Likert-scale items:

In science teaching, simulations are…

1 2 3 4 5 6 7
very useless not useless but also not useful very useful

After this project I think about using simulations in my own science teaching…

1 2 3 4 5 6 7
very negatively not negatively but also not positively very positively

Open questions:

What kinds of possibilities are involved in using simulations in primary school science teaching?

What kinds of weaknesses are involved in using simulations in primary school science teaching?

What kind of know-how does a teacher need in order to use simulations in his/her teaching?

ORIGINAL PAPERS

I

PRESERVICE TEACHERS' TPACK BELIEFS AND ATTITUDES TOWARD SIMULATIONS

by

Lehtinen, A., Nieminen, P. & Viiri J., 2016

Contemporary Issues in Technology and Teacher Education, 16(2), 151-171

Lehtinen, A., Nieminen, P., & Viiri, J. (2016). Preservice teachers' TPACK beliefs and attitudes toward simulations. *Contemporary Issues in Technology and Teacher Education, 16*(2), 151-171.

Preservice Teachers' TPACK Beliefs and Attitudes Toward Simulations

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Abstract

This study investigated the effect of an intervention regarding the use of simulations in science teaching on primary school preservice science teachers' (n = 36) self-assessed technological, pedagogical, and content knowledge (TPACK). The connection of their self-assessed TPACK on their views on the usefulness of simulations in science teaching and on their disposition toward integrating simulations in their teaching was also studied. The results showed statistically significant differences between preservice teachers' pre- and posttests in content knowledge, pedagogical knowledge, and TPACK domains. Preservice science teachers' technological knowledge correlated with their views on the usefulness of simulation and disposition toward integrating simulations in teaching. The implication for science teacher training is that more attention should be paid to developing preservice teachers' beliefs about their technological knowledge throughout their teacher training in order to encourage them to use simulations in science teaching.

Preservice teachers' beliefs have a large influence on their choice to use technology in their teaching (Chen, 2010). In science teaching, one of the most widely used forms of technology is computer simulations. The learning effects of simulations in secondary level science education have been extensively documented (Rutten, van Joolingen, & van der Veen, 2012). Less research is available on primary-age learners and simulations (Zacharia, Loizou, & Papaevripidou, 2012). At the primary level the best learning effects are achieved by combining learning with computer simulations and learning with laboratory experiments, compared to both methods on their own (Jaakkola & Nurmi, 2008).

When looking at the use of simulations at a curricular level, the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) in the US are based on the *Framework for K-12 Science Education* (Schweingruber, Keller, & Quinn, 2012). This framework identifies eight scientific and engineering practices that should be promoted in science classrooms. Of those eight practices, two are closely related to learning with simulations: "developing and using models" and "using mathematics and computational thinking."

This study reports an intervention carried out with preservice primary teachers regarding the use of simulations in science teaching. The aims of the study were (a) to study the preservice teachers' beliefs about their technological, pedagogical, and content knowledge (TPACK), measured through self-assessment before and after the intervention and (b) to find out the possible connections between preservice teachers' beliefs regarding the different domains of knowledge and their attitudes toward simulations in science teaching.

First to be considered in this paper are the role of beliefs, in general, in technology integration, which is followed by discussion of the TPACK framework. Last is an argument that self-assessing TPACK is a way to study beliefs.

Background

Defining Beliefs and Attitudes

In a study of beliefs and attitudes, the concepts need to be defined. Koballa (1989) stated that beliefs link objects and attributes together. An example of a belief would be "Using computers (object) is hard (attribute)." We define attitudes similarly to Zacharia (2003), as mental concepts that depict favorable or unfavorable feelings toward a person, group, policy, instructional strategy, or particular discipline. An example of an attitude is, "I don't like computers." According to Koballa, a person has more beliefs than attitudes.

In this paper, the preservice teachers' views on the usefulness of simulations in science teaching and their dispositions toward integrating simulations in their teaching are seen as different domains of their attitude toward simulations, because both of these constructs reflect their favorable or unfavorable feelings toward simulations.

Teacher Beliefs, Attitudes and Technology Integration

Moving from defining beliefs into research on teacher beliefs, the role of them in technology integration in teaching has been under research during the last decade. Regarding preservice teachers, their self-assessed technological skills, teacher training program experiences, and beliefs about the usefulness of technology in teaching and learning influence their choice to use technology in teaching (Chen, 2010).

Abbitt (2011) studied the connection between preservice teachers' self-assessed knowledge related to teaching with technology and their beliefs in their ability to use technology in their teaching. His results suggested that improving preservice teachers' knowledge regarding teaching with technology may result in increased beliefs in their ability to teach efficiently using technology. With in-service teachers, those teachers who had successfully integrated technology in their teaching reported internal factors, such as having a passion for technology and having a problem solving mentality, as important factors in shaping their practices for using technology (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012).

Concerning beliefs and attitudes relating to teaching science with simulations, Zacharia (2003) studied both preservice and in-service teachers' beliefs about the advantages and disadvantages regarding the use of computer simulations in science education. His results showed that teachers' attitudes toward using simulations in science teaching were related to their beliefs about the positive learning outcomes of using simulations.

Zacharia, Rotsaka, and Hovardas (2011) came to the same conclusion in their study with in-service teachers, but they also found a possible connection with beliefs about the usefulness of simulations in teaching and the attitude toward using simulations. Kriek and Stols (2010) listed the perceived usefulness and compatibility of simulations, expectations of colleagues, and teachers' general technological proficiency as being connected with simulation usage.

Overall, teacher beliefs are seen as important factors when looking at technology integration, both with in-service (Ertmer et al., 2012) and preservice teachers (Chen, 2010). Teacher beliefs are even seen as more influential in teaching than is teacher knowledge (Pajares, 1992). In addition, professional development programs that do not take into account teacher beliefs and attitudes have been unsuccessful (Ryan, 2004; Stipek & Byler, 1997).

This study aimed to add to the literature about ways that preservice teachers' beliefs in different domains measured through self-assessed knowledge are connected with their attitudes toward simulations. The TPACK framework was used to study the preservice teachers' beliefs on technology in science teaching.

The TPACK Framework

The TPACK framework was introduced by Koehler and Mishra (2005), who originally used the term "technological pedagogical content knowledge," or "TPCK." The TPACK framework aims to integrate technology into the same framework as pedagogy and content (Mishra & Koehler, 2006). This integration is supported by research suggesting that learning only technological skills do not prepare teachers and educators to integrating technology in their content-specific teaching (Lawless & Pellegrino, 2007). One way to illustrate the TPACK framework is by using a Venn diagram (see Figure 1).

Here, pedagogical knowledge (PK), content knowledge (CK), and technological knowledge (TK) are presented as three circles. In the intersections of the circles are pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK). In the middle, where all three circles intersect, is the technological pedagogical content knowledge. In this paper, these forms of teacher knowledge are referred as the domains of the TPACK framework.

Critique of the TPACK Framework

The TPACK framework in the form formulated by Mishra and Koehler and represented in Figure 1 has been criticized. Brantley-Dias and Ertmer (2013) criticized the framework as having too many domains of knowledge that are impossible to distinguish from each other. Archambault and Barnett (2010) also raised the issue that separating the domains from each other is difficult. They reported that in their survey study teachers placed items into different domains than the researchers had intended, which raised a question about the existence of all of these knowledge domains in practice.

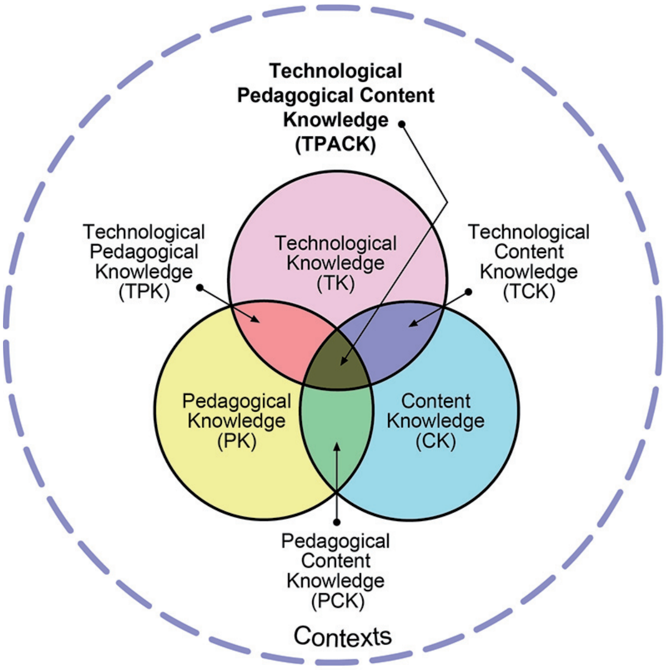

Figure 1. *An illustration of the TPACK framework. Reproduced by permission of the publisher, © 2012 by tpack.org*

Even when taking into account the criticism, however, the TPACK framework has succeeded in bringing attention to the need to consider how teachers' knowledge of technology can support students' learning (Brantley-Dias & Ertmer, 2013). The framework offers a chance for researchers, teachers and educators to conceptualize how technology can improve teaching and learning (Archambault & Barnett, 2010).

Preservice Teachers' TPACK

The critique of the TPACK framework and the issue of distinguishing the different domains of knowledge from one another can be especially noteworthy with preservice teachers, who might not have the necessary understanding to categorize their knowledge into the different TPACK domains (Chai, Ling Koh, Tsai, & Lee Wee Tan, 2011). The still-forming TPACK of preservice teachers has been described as emerging TPACK (Ozgun-Koca, Meagher, & Edwards, 2010) or proto-TPK (Kontkanen et al., 2014).

Preservice teachers even unknowingly bring their own technological experiences from their education, free time, and university courses to their teaching (Kontkanen et al., 2014). These previous experiences affect the way the preservice teachers plan and assess the use of technology in their teaching as well as in the development of their TPACK (Hofer & Grandgenett, 2012; Hofer & Harris, 2010; Ozgun-Koca et al., 2010). Maeng, Mulvey, Smetana, and Bell (2013) suggested that science teaching method courses should emphasize the role of technology in supporting pedagogical approaches in teaching the specific content.

Soon after the TPACK framework was developed, it became obvious that ways to measure TPACK empirically were needed (Koehler, Shin, & Mishra, 2012). Perhaps the most widely used survey for preservice teachers to self-assess their TPACK is the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009). Schmidt et al.'s survey has been shown to have acceptable validity and reliability in modifications (Chai, Koh, & Tsai, 2010; Koh, Chai, & Tsai, 2010).

Lin, Tsai, Chai, and Lee (2013) took the Survey of Preservice Teachers' Knowledge of Teaching and Technology and revised it to fit preservice science teachers. Lin et al.'s survey consisted of 27 items divided into the seven TPACK domains. The researchers reported satisfactory validity and reliability for their survey. Zelkowski, Gleason, Cox, and Bismarck (2013) took the survey by Schmidt et al. and modified it for preservice secondary mathematics teachers. Zelkowski et al. reported good internal reliability for the test but noted that they were not able to produce meaningful factors for the PCK, TPK and TCK domains, which is consistent with the previously discussed issue of separating the domains of TPACK from one another. The final survey by Zelkowski et al. (2013) contained 22 items restricted only to the TK, CK, PK, and TPACK domains.

Self-Assessed TPACK as a Way to Study Beliefs

Self-assessment instruments for teachers' TPACK have been argued to measure preservice teachers' personal beliefs about their knowledge (Zelkowski et al., 2013) and in-service teachers' confidence (Graham et al., 2009). In general, Pajares (1992) stated that knowledge and beliefs are inextricably intertwined.

We argue the same: Using self-assessment to study preservice teachers' knowledge in different domains is also a way to study their personal beliefs in these domains. One's own assessment of one's knowledge in an area is intertwined with one's personal beliefs related to that area, because beliefs also have a cognitive component dealing with context-specific knowledge (Herrington, Bancroft, Edwards, & Schairer, 2016). Thus, the preservice teachers' self-assessment of their knowledge in the different TPACK domains may be used as a method of measuring their beliefs related in these domains. This study moves the literature forward in taking into account both the research of teachers' beliefs regarding technology and the research related to the TPACK framework by using preservice teachers' self-assessed TPACK as an indicator of their beliefs in the different domains.

Study Aim and Research Questions

The first aim of this study was to gain insight into developing preservice primary teachers' self-assessed TPACK in science through an intervention in which they were acquainted with using simulations in science teaching. The second aim was to study the possible connection of preservice teachers' beliefs measured through their self-assessed knowledge in the different domains of the TPACK framework with their attitudes toward simulations. The results of this study can be used to develop the teaching related to simulations in science teaching during preservice teacher training.

The research questions and hypotheses are as follows:

1. How do primary school preservice teachers' TK, PK, CK, and TPACK related beliefs measured through self-assessment differ when comparing the results before and after the intervention?Based on the design of our intervention, we

expected the preservice teachers' beliefs of their knowledge to improve in the CK and TPACK domains.

2. How do preservice teachers' beliefs measured through their self-assessed knowledge in the different domains of the TPACK framework affect their views on the usefulness of simulations in science teaching?According to Teo (2009) preservice teachers' self-assessed computer using skills had an effect on their assessment of usefulness of technology in teaching. Thus, we expected the preservice teachers' beliefs related to TK to correlate with their views on the usefulness of simulations in science education.
3. How do preservice teachers' beliefs measured through their self-assessed knowledge in the different domains of the TPACK framework affect their disposition toward integrating simulations into teaching? According to Ertmer et al. (2012) teachers' passion for technology affects their technology integration practices. Also, Abbitt (2011) showed that the only domain of the TPACK framework that predicted their confidence in their ability to integrate technology into teaching before and after their intervention was the preservice teachers' TK. Thus, we expected the preservice teachers' beliefs related to TK to correlate with their attitudes toward integrating simulations into their science teaching.

Study Context and Participants

The study was conducted as an intervention that was a part of a science pedagogy course in the primary teacher program at University of Jyväskylä in Finland. Preservice teachers enrolled in the course were offered the chance to participate in the intervention. All (n = 40) agreed to participate voluntarily, but only 36 of them completed all of the study instruments.

The preservice teachers were between the ages of 20 and 42, with the average age being 24.2. Thirty-one of them were female and five were male, the typical gender distribution in Finnish primary-level teacher education. Twenty-three preservice teachers reported having less than 6 months of teaching experience, and one reported having more than 2 years of experience. The rest had teaching experience ranging between 6 months and 2 years.

The preservice teachers were in different phases of their studies, ranging from their second year to the fifth year of the 5-year master of education program. The preservice teachers majored in special education, but they had chosen primary teacher studies as their minor. Only one preservice teacher of the 36 had previous experience using simulations in science learning or teaching, so the intervention served as an introduction to simulations.

Study Design and Methods

The study used a single-group pretest-posttest design to study the possible changes in the preservice teachers' beliefs related to TPACK over time. The data was collected before and after the intervention focusing on using simulations in science teaching.

Measuring Preservice Teachers' TPACK With Self-Assessment

The TPACK survey used in this study (Appendix A) was adapted from Lin et al.'s (2013) and Zelkowski et al.'s (2013) studies. The items about different areas of mathematics (algebra, geometry, etc.) in Zelkowski et al.'s (2013) study were changed to items about different science subjects, since these subjects (physics, chemistry, biology, and geography) are taught together in Finnish primary schools from grades 1 to 6 and they are covered in the same science methods course as a part of the primary teacher training program at University of Jyväskylä.

The final survey contained 29 seven-level Likert items (28 positively phrased and 1 negatively phrased) divided into four knowledge domains, CK, PK, TK, and TPACK. The decision not to include the three other knowledge domains from the TPACK framework was based on Brantley-Dias's and Ertmer's (2013) critique to the TPACK framework and the fact that our survey instrument was adapted from Zelkowski et al. (2013), who could not produce meaningful factors for these domains.

Example items, the number of items per TPACK domain, and Cronbach alphas for the pre- and posttest are presented in Table 1. All scales on the pre- and posttests met the threshold criteria commonly adopted of Cronbach alpha > .80, indicating good reliability. The survey was administrated via an online form before the intervention and after the preservice teachers had taught their lesson.

Table 1
Example Items From the TPACK Survey and the Reliability of Its Domains

TPACK Domain	Example Item	No. of Items	Cronbach's Alpha - Pretest	Cronbach's Alpha - Posttest
CK	I have various strategies for developing my understanding of science.	7	.87	.87
PK	I am able to help my students to monitor their own learning.	8	.87	.92
TK	I know how to solve my own technical problems when using technology.	8	.93	.93
TPACK	Integrating technology in teaching science will be easy and straightforward for me.	6	.91	.90
Overall		29	.94	.94

Measuring Preservice Teachers' Attitudes Toward Simulations in Science Teaching

The data for the preservice teachers' views on the usefulness of simulations in science teaching and their disposition toward integrating simulations in their science teaching was collected by 7-point Likert-scale items (Appendix B). These data were collected by paper during the last intervention meeting.

The Course of the Intervention

The 40 preservice teachers took part in the intervention in two groups of 20 teachers each. The intervention was implemented during 8 weeks, consisting of group meetings, lesson planning, and teaching a lesson. The intervention started with five weekly meetings that lasted 90 minutes each. These meetings revolved around inquiry-based teaching of science with simulations. During and between these meetings, the preservice teachers planned a physics lesson for the primary level in which they used simulations.

Physics was chosen as the subject because of the abundance of simulations that can be used in primary level physics. The lessons were planned and taught in groups of five. After the lessons all 40 of the preservice teachers participated in a final meeting that lasted 3 hours. The content of all the meetings was the same for both groups. Between the meetings, the preservice teachers worked on their own lesson planning. The course of the intervention is presented in Table 2.

Table 2
The Course of the Intervention

Week	Event /Meeting	Content of the Meeting
1	TPACK pretest	
1	Inquiry learning	Introduction to the basics of inquiry learning in science.
2	Simulations in science education	Introduction to the research results concerning the use of simulations and a chance to try some PhET simulations.
3	Dividing the subgroups and handing out lesson topics	The two groups of 20 preservice teachers were each divided into four groups of five. These subgroups were each given a topic to plan a physics lesson about in which they had to use a given PhET simulation.
4	Planning the lessons	The subgroups revised the science content of their topic and presented their preliminary lesson plans.
5	Planning the lessons	The subgroups presented their final lesson plans.
6 - 7	Teaching the lessons	
7	TPACK posttest	
8	Final meeting and end survey (Appendix B)	The preservice teachers had a chance to share their feelings and experiences on teaching with simulations with their peers.

The topics for the lessons taught by the preservice teachers were based on the Finnish national curriculum and were decided by the teachers of the two primary schools in which the lessons were taught. The simulations used were also decided together with the teachers to suit the progress of their pupils in their science studies. The simulations chosen for the lessons were all Physics Education Technology (PhET) simulations (retrieved from http://phet.colorado.edu/en/simulations/), which were chosen because simulations were available for each science subject and for mathematics. The PhET simulations were, thus, a good resource for primary school teachers, who must teach every science subject. The pupils in these schools ranged from third graders (10-year-olds) to sixth graders (13-year-olds). The lesson topics and simulations used are presented in Table 3.

Data Analysis

Individual Likert scale items should be considered an ordinal level of measurement, but combining multiple Likert scale items into one construct allows the construct to be treated as an interval level of measurement (Carifio & Perla, 2007, 2008). A one-sided paired sample *t*-test was used to answer Research Question 1. A one-sided test was used because it can be assumed that the change is positive when comparing the answers on the pre- and posttests.

Table 3
The Topics of the Lessons and PhET Simulations Used by the Preservice Teachers in the Lessons

Topic	PhET Simulation Used
Static Electricity	Balloons and Static Electricity
Forms of Energy	Energy Skate Park: Basics.
DC Circuits	Circuit Construction Kit (DC Only)
Balance	Balancing Act

The linear correlations between the different domains of knowledge can be studied using Pearson's product-moment correlation coefficient (Pearson's *r*; Carifio & Perla, 2007), but the correlation between the preservice teachers' beliefs in the different domains and their attitudes toward simulations should be measured using, for example, Spearman's rank correlation coefficients (Spearman's ρ), because the data from individual Likert items is ordinal in nature (Carifio & Perla, 2008). In this paper, both types of correlation coefficients are presented in a single table for reasons of clarity, even though they are not meant to be compared with each other.

The analysis for Research Questions 2 and 3 depended on the preservice teachers' answers to individual Likert scale items. Some researchers generally avoid this approach in research (Carifio & Perla, 2007), but others state that in some cases a single-item measure can be used (Gardner, Cummings, Dunham, & Pierce, 1998; Wanous, Reichers, & Hudy, 1997). Trying to come up with different items or synonyms to measure the same construct (e.g., preservice teachers' views of the usefulness of simulations) may have increased the chance to include items that are not proper synonyms of, for example, *usefulness,* which is a problem raised by Drolet and Morrison (2001).

Results

The results are presented in three sections, each based on one of the research questions.

Self-Assessed TPACK Before and After the Intervention

The possible relations between the knowledge domains and their relative stability were studied by calculating their Pearson's product-moment correlation coefficients (Table 4).

The results show that all of the knowledge domains are separate. The correlations between the domains are low enough that they can be called separate from each other. The squared correlation coefficients are presented in Table 5. More than half of the beliefs measured by self-assessed knowledge in any domain could not be directly accounted to any other domain, with the only exception being the PK-TPACK (post) correlation. Therefore, the use of, for example, Bonferroni correction when using paired sample *t*-tests was not necessary. Also, the domains of knowledge were relatively quite stable when the pre- and posttests were compared, especially the CK, PK, and TK domains (see the correlations in Table 4); that is, the same preservice teachers who assessed their knowledge in these domains high in the pretest also assessed it high in the posttest.

Table 4
Correlation Coefficients for the Domains of Knowledge

Area of Study	1.[a]	2.[a]	3.[a]	4.[a]	5.[a]	6.[a]	7.[a]	8.[a]	9.[b]	10.[b]
1. CK – pre[a]	-									
2. PK – pre[a]	.43**	-								
3. TK - pre[a]	.16	.36*	-							
4. TPACK - pre[a]	.33*	.57**	.62*	-						
5. CK - post[a]	.69**	.35*	.19	.25	-					
6. PK - post[a]	.32*	.61**	.30	.23	.56**	-				
7. TK - post[a]	.16	.34*	.88**	.57**	.36*	.40*	-			
8. TPACK - post[a]	.28	.45*	.39*	.37*	.59**	.75**	.50**	-		
9. Usefulness[b]	.03	.08	.41*	.22	.-17	.-11	.39*	.09	-	
10. Integration[b]	.11	.17	.48**	.30	.00	.09	.44**	.19	.59**	-

* $p < .05$; ** $p < .01$
[a] Pearson's r
[b] Spearman's ρ

Table 5
Squared Correlation Coefficients for the Domains of Knowledge

Domains of Knowledge	Squared Correlation Coefficient - Pretests	Squared Correlation Coefficient - Posttests
CK - PK	.19	.31
CK – TK	.03	.13
CK - TPACK	.11	.35
PK – TK	.13	.16
PK - TPACK	.32	.56
TK - TPACK	.38	.32

The means and standard deviations from the pre- and posttests for the different domains of knowledge are presented in Table 6. The metric used to estimate and describe the change in the preservice teachers' beliefs regarding the different domains of the TPACK framework was Cohen's *d,* with the square root of the average of the pre- and posttests' standard deviations squared as the standardizer (see rationale in Cumming, 2012, p. 291). Cohen's *d* values of $0.20 < d < 0.50$ represent a small effect, values of $0.50 < d < 0.80$ represent a moderate effect, and values $0.80 < d$ represent a large effect (Cohen, 1988).

Table 6
Results From the TPACK Survey

Domain of Knowledge / Attitude	Pretest		Posttest				
	M	***SD***	**M**	***SD***	***t*-value**	***p*-value**	**Cohen's *d*-value**
CK	3.23	.90	3.65	.95	3.52	< .001	.45
PK	4.23	.78	4.85	.82	5.21	< .001	.77
TK	3.65	1.29	3.76	1.17	1.04	< .15	.09
TPACK	2.97	.81	4.20	.98	7.28	< .001	1.37

The mean scores for the all of the four TPACK domains were higher on the posttest than on the pretest; TK was the only domain for which the difference was not significant at the .05 level. The effect sizes for the rest of the domains ranged from small to large.

TPACK and View of the Usefulness of Simulations in Science Teaching

The correlations between the beliefs related to different domains of the TPACK framework and the preservice teachers' view of the usefulness of simulations in science teaching are presented in Table 4. TK was the only domain with a statistically significant correlation at the .05 level with the preservice teachers' views on the usefulness of simulations in science teaching in the pre- and posttests. The correlation coefficients show a low positive correlation (Hinkle, Wiersma, & Jurs, 2003).

TPACK and Disposition Toward Integrating Simulations Into Science Teaching

The correlations between the beliefs related to different domains of the TPACK framework and the preservice teachers' disposition toward integrating simulations into their science teaching are presented in Table 4. TK was the only domain with a statistically significant correlation at the .05 level with the preservice teachers' disposition toward integrating simulations in their science teaching from the pretest and posttest. The correlation coefficients show a low positive correlation (Hinkle et al., 2003).

Study Validity and Limitations

The study group represented about 25% of the annual intake of primary teacher students at the University of Jyväskylä. The age and gender distribution were typical for primary teacher education in Finland. Thus, the results of this study can be representative of the cohort group of the entire primary teacher student population of the university but may not be generalizable across all contexts and populations.

The validity of the survey used in this study cannot be determined using statistical methods due to the small size of the study group. However, the survey was adapted from two validated surveys (Lin et al., 2013; Zelkowski et al., 2013), and it had good reliability (see Table 1). As with all self-report scales, the results may be biased, because the participants of the study may give socially desirable answers. Also, the age and the gender distribution of the participants might have had an effect on their answers.

We do not claim that the TPACK survey used in this study measures objectively what the preservice teachers knew. The self-assessed knowledge was used to study the preservice teachers' beliefs about their knowledge in the TPACK domains. Preservice teachers can be overconfident about their skills or may lack confidence (Zelkowski et al., 2013).

Also, although attributing the change in self-assessed knowledge to any specific activity is not possible, the participants of the study were engaged in developing and thinking about their technology integration practices in science teaching through planning the lessons and the using simulations in their teaching. The change in their self-assessed knowledge can be reasonably attributed to this activity.

Discussion

The results from the study indicate that the introduction to simulations in science described in this paper had a medium to large effect on the preservice teachers' beliefs in the CK, PK and TPACK domains of the TPACK framework, which partly confirmed our expectations under Research Question 1. The possible reasons for the change in beliefs in the different domains must be looked at separately.

As a part of the intervention, the preservice teachers had to revise the scientific content relating to the subjects of their lessons, possibly explaining the change in beliefs in the CK domain. The change in beliefs related to the PK domain is interesting, considering the fact that the items in the survey instrument relating to PK were not related to PCK in science but to general PK. The preservice teachers possibly could not distinguish between general PK and PCK relating to science teaching, possibly due to their lack of experience with teaching science.

The change in the beliefs in the TK domain was not statistically significant at the .05 level. This result was to be expected because the focus of the intervention was on ways simulations can be used in science teaching and not in general TK.

The effect size was the largest in the beliefs related to the TPACK domain. This result is encouraging, taking into account the fact that the whole focus of the intervention was to give preservice teachers experience in integrating one application of educational technology into science teaching. The intervention increased the preservice teachers' beliefs in their ability to plan and execute science lessons that integrate technology.

Preservice teachers' belief in their TK correlated with their views on the usefulness of simulations in science teaching, which confirmed our expectation under Research Question 2. Their disposition toward integrating simulations into their science teaching also correlated with their belief in their TK, which confirmed our expectation under Research Question 3. Our observations during the intervention on the preservice teachers' technological skills were that they all possessed the technological skills required to operate computer simulations from a technical viewpoint. The preservice teachers' attitudes toward simulations may not be linked to the actual presence or lack of technological knowledge and skills required to use the simulations but to the preservice teachers' conceptions about themselves as users of technology.

With in-service teachers earlier research findings showed a connection between personal interest in technology and successful integration of technology in teaching (Ertmer et al., 2012). Our results support the same connection, because having a personal interest in technology probably increased their belief in their TK. The results of this study add to the literature in connecting preservice teachers' beliefs about their TK to their attitudes toward technology in teaching.

The fact that the belief in the TK domain correlated with the preservice teachers' attitude toward simulations and not the TPACK domain provides new support for the previous claims that preservice teachers' views of their PK are still being formed (Kontkanen et al., 2014; Ozgun-Koca et al., 2010). It might be easier for the preservice teachers to assess their TK than their ability to plan and carry out science lessons in which technology is used appropriately because they lack experience. They probably had not had chances to try out teaching science with technology before the intervention. This would cause the preservice teachers' assessment of their TPACK to be based more on expectations and assumptions than actual reflection. However, the preservice teachers had a better grasp on their TK because they came in contact with technology every day and, thus, had a chance to form a conception of themselves as users of technology.

Implications

The results show that the belief in the TK domain correlated with the preservice teachers' attitudes toward simulations in both the pre- and posttests. This result implies that our intervention did not change the fact that the more technologically confident preservice teachers were more positive toward integrating simulations in their teaching and saw simulations as being more useful. Previous research has shown that teachers' internal factors related to technology integration are hard to change, because they require teachers to confront their existing beliefs and to apply a new view of doing and seeing things to their learning (Polly, Mims, Shepherd, & Inan, 2010). The results from this study supported that claim.

Because preservice teachers' TK correlates with their attitudes toward simulations, efforts to increase preservice teachers' TK and self-confidence should be made throughout their teacher training. This strategy may raise the preservice teachers' beliefs in their TK and improve their attitudes toward simulations.

At the same time, courses dealing with science should include chances to use technology in supporting different pedagogical approaches (Maeng et al., 2013). Zacharia et al. (2011) argued that preservice teachers should be exposed to the learning and teaching benefits of simulations during their teacher training, while also developing the competencies related to teaching science with simulations throughout their studies. In general, a focus on content, pedagogy, and technology at all stages of the teacher training programs would benefit future technology integration (Koehler & Mishra, 2009).

The results of this study and the implications made are reinforced by psychological research on achievement motivation and behavior. Eccles at al. (1983) developed an expectancy-value model of achievement choice originally in order to study children's and adolescents' performance and choice in mathematics. The model has developed since then, and the most recent version (Wigfield & Eccles, 2000) has also been used to study learning motivation on adults (Gorges & Kandler, 2012). Among other factors, the model states that self-concept of one's abilities and sense of importance or utility is related to achievement-related choices.

The results of this study fit that model. In this study, a correlation was found between the preservice teachers' beliefs about their TK (self-concept of abilities) and both their views on the usefulness of simulation (sense of utility) and their dispositions toward integrating simulations into their science teaching (achievement-related choice). This result combined with the expectancy value-model of achievement emphasized the argument that preservice teachers' beliefs about their TK should be developed throughout their teacher training in order to encourage them to integrate simulations in science teaching.

Suggestions for Future Research

Conducting interviews with the preservice teachers would give insight into their personal views on technology integration in their teaching. In addition, following the same preservice teachers from their teacher training program to their work as primary school teachers would provide information on the actual integration of simulations into teaching. Using the same study methods with in-service science teachers in a professional development program would enable researchers to study the role of self-assessed knowledge in different domains in using simulations in science teaching.

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This study was funded by a grant from the Technology Industries of Finland Centennial Foundation.

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Appendix A
The TPACK Survey

The answers for all the items are given using a 7-point Likert scale (1 = *I disagree strongly*, 7 = *I agree strongly*), L = (Lin et al., 2013), Z = (Zelkowski et al., 2013)

CK1: I have sufficient knowledge of science to teach science. L

CK2: I can think about the content of science like a subject matter expert. L

CK3: I have various strategies for developing my understanding of science. Z

CK4: I have a deep and wide understanding of biology. Z

CK5: I have a deep and wide understanding of physics. Z

CK6: I have a deep and wide understanding of geography. Z

CK7: I have a deep and wide understanding of chemistry. Z

PK1: I am able to stretch my students' thinking by creating challenging tasks for them. L

PK2: I am able to guide my students to adopt appropriate learning strategies. L

PK3: I am able to help my students to monitor their own learning. L

PK4: I am familiar with common student understandings and misconceptions. Z

PK5: I know when it is appropriate to use a variety of teaching approaches (e.g., problem/project- based learning, inquiry learning, collaborative learning, direct instruction) in a classroom setting. Z

PK6: I know how to assess student performance in a classroom. Z

PK7: I can assess student learning in multiple ways. Z

PK8: I can adapt my teaching based upon what students currently understand or do not understand. Z

TK1: I have the technical skills to use technology effectively. L

TK2: I can learn technology easily. L

TK3: I know how to solve my own technical problems when using technology. L

TK4: I keep up with important new technologies. L

TK5: I have had sufficient opportunities to work with different technologies. Z

TK6: I frequently play around with the technology. Z

TK7: I know a lot about different technologies. Z

TK8: When I encounter a problem using technology, I seek outside help. Z (negatively phrased)

TPACK1: I can teach lessons that appropriately combine biology, technologies, and teaching approaches. Z

TPACK2: I can teach lessons that appropriately combine physics, technologies, and teaching approaches. Z

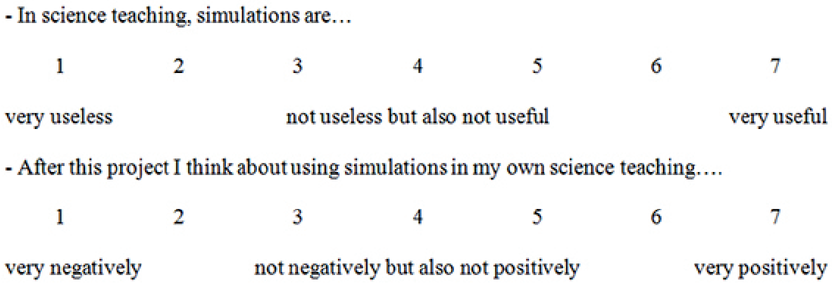
TPACK3: I can teach lessons that appropriately combine geography, technologies, and teaching approaches. Z

TPACK4: I can teach lessons that appropriately combine chemistry, technologies, and teaching approaches. Z

TPACK5: I can provide leadership in helping others to coordinate the use of science, technologies, and teaching approaches in my school and/or district. L

TPACK6: Integrating technology with teaching science will be easy and straightforward for me. Z

Appendix B
Items About Attitudes Toward Simulations



- In science teaching, simulations are…

1	2	3	4	5	6	7
very useless			not useless but also not useful			very useful

- After this project I think about using simulations in my own science teaching….

1	2	3	4	5	6	7
very negatively			not negatively but also not positively			very positively

II

PRE-SERVICE PRIMARY TEACHERS' BELIEFS OF TEACHING SCIENCE WITH SIMULATIONS

by

Lehtinen, A., Nieminen, P., & Viiri, J., 2016

J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto, & K. Hahl (Eds.), Electronic Proceedings of the ESERA 2015 Conference. Science Education Research: Engaging Learners for a Sustainable Future (pp. 1949-1959). ESERA Conference Proceedings, 4. Helsinki, Finland: University of Helsinki.

PRE-SERVICE PRIMARY TEACHERS' BELIEFS OF TEACHING SCIENCE WITH SIMULATIONS

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Abstract: Although the benefits of the use of simulations in science education have been extensively documented, research on pre-service teacher education related to the use of simulations in science teaching remains limited. The aim of this study was to investigate the beliefs of pre-service primary teachers in two teacher training programs of two different universities (n = 36 and n = 18) related to teaching science with simulations. The teachers participated in an intervention where they planned and gave a science lesson where simulations were used. The effect of the two different types of interventions on the beliefs was also studied. The Interconnected Model of Professional Growth by Clarke and Hollingsworth is used as a framework for the effect that the intervention has on the beliefs. The data was collected through post-intervention surveys with open questions. After the both interventions pre-service teachers perceived the simulations' ability to demonstrate otherwise unobservable phenomena and motivate the learners' as their advantages and appropriate use of simulations in relation to the learning goals was seen a challenge. Likewise, all pre-service teachers viewed technological and pedagogical knowledge as important know-how for teachers when teaching with simulations. There were differences in the conceptions after the two interventions, mostly related to the weaknesses of simulations and the teacher know-how needed. These can be explained with the differences between the interventions. The results confirm the impact that external stimuli such as these kinds of interventions have on teachers' beliefs. It is vital to design teacher training for simulations in a way that offers just the right amount of support to enable the future teachers to be able to start teaching science with simulations.

Keywords: Simulations, teacher beliefs, pre-service teachers

INTRODUCTION

Technology and teacher beliefs

The benefits of computer simulations in science teaching have been widely studied during the past 15 years (Rutten, van Joolingen, & van der Veen, 2012). The conclusion from these studies is that the use of computer simulations can enhance science instruction, especially as far as laboratory activities are concerned (Rutten et al., 2012). They have a positive effect on learning, learner attitudes and motivation (Rutten et al., 2012; Smetana & Bell, 2012).

Even though the learning benefits of simulations are accepted, they are perhaps not used to their full extent. The results from the international Trends in International Mathematics and Science Study (TIMMS) from the year 2011 state that on average 25% of the 4th graders who participated in the study were asked to study natural phenomena through simulations at least monthly (Martin, Mullis, Foy, & Stanco, 2012). The lack of computer resources can have an effect on this but also in countries like Finland where 66% of students have access to computers for their science lessons just 15% of the 4th graders were asked to study natural phenomena through simulations at least monthly (Martin et al., 2012).

When looking at factors that affect teachers' use of technology in classrooms, two sets of barriers have been distinguished (Ertmer & Hruskocy, 1999; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). The *first-order* barriers are external to the teacher and include access to hardware and software, training and support. The *second-order* barriers comprised those that are internal to the teacher and include confidence to use technology, beliefs about student learning and perceived value of technology for their teaching and students' learning. Beliefs link objects and attributes together (Koballa, 1989). An example of a belief would be "Using computers (object) in teaching is beneficial (attribute) for learning". The second-order barriers are thought to pose a larger challenge for technology integration to classrooms (Ertmer & Hruskocy, 1999; Ertmer et al., 2012). Teacher beliefs are seen as vital to consider in order to facilitate technology integration in classrooms (Kim, Kim, Lee, Spector, & DeMeester, 2013). Pre-service teachers' experiences from their teacher training program and beliefs about the usefulness of technology in teaching and learning influence their choice to use technology in teaching (Chen, 2010). The role of pre-service teachers' technological, pedagogical and content knowledge (Koehler & Mishra, 2009; Mishra & Koehler, 2006) on the integration of technology in their teaching has also been studied. The results show that pre-service teachers' self-assessed knowledge related to technology in teaching has a correlation with their self-efficacy beliefs related to technology integration (Abbitt, 2011) and that pre-service teachers' self-assessed technological knowledge is connected to their perception towards integrating simulations into their teaching (Lehtinen, Nieminen, Viiri, 2015).

Literature shows, that in order to develop pre-service teacher training regarding the use of simulations, there is a need to study the beliefs pre-service teachers have on teaching science with simulations. By looking at the role that teacher training has on these beliefs, this training can be further develop to lower the second-order barriers to simulation integration discussed earlier and this way possibly increase the use of simulations in science classrooms.

Theoretical background

The role of teacher knowledge, beliefs and attitudes on their work has been studied from different perspectives. Fullan (1982) viewed that change in teachers' knowledge and beliefs preceded the change in classroom practices. On the other hand, Guskey (1986) modeled teacher change in a way where change in classroom practice preceded the change in teachers' beliefs and attitudes. Clarke and Hollingsworth (2002) formulated their own model of teacher change which was a cyclical process. Their Interconnected Model of Professional Growth is presented in Figure 1.

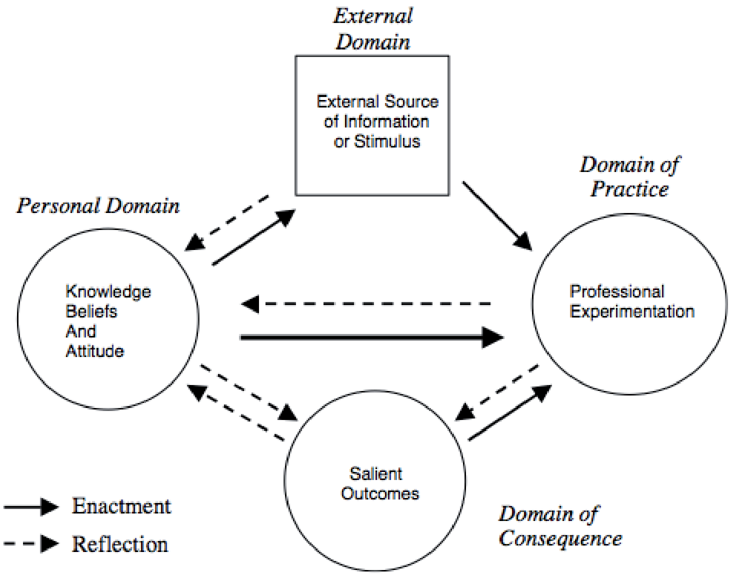

Figure 1. The Interconnected Model of Professional Growth by Clarke and Hollingsworth (2002).

The model states that teacher change occurs through the processes of enactment and reflection between four different domains. These domains are the external domain (information, stimulus or support), the personal domain (knowledge, beliefs and attitudes), the domain of practice (professional experimentation) and the domain of consequence (salient outcomes). The model highlights the effect that external information or stimulus, such as interventions or courses of teacher training programs, have on teachers' beliefs and attitudes and their professional experimentation. Different kinds of stimuli can result in differences in teachers' beliefs and attitudes.

Our study

The aim of this study is to find out what kinds of conceptions do pre-service primary teachers have about teaching science with simulations. An area of interest is also their conception on what kinds of know-how does a teacher need to have in order to teach science with simulations. This reveals if the pre-service teachers' think that teaching with simulations needs e.g. content knowledge or technological knowledge. Also, because the data comes from two different universities, the effect of different external stimuli related to teaching science with simulations on the pre-service teachers' beliefs can be studied according to the Interconnected Model of Professional Growth by Clarke and Hollingsworth (2002). In the discussion section of this paper we aim to explain the possible differences in the beliefs with the content of the interventions.

Our research questions are as follows:

1. What kinds of beliefs do pre-service teachers have about teaching science with simulations after participating in an intervention on the subject?
2. What kinds of teacher know-how do pre-service teachers view as important when teaching science with simulations?

3. What kind of differences are in these beliefs and teacher know-how when the two different interventions are compared?

METHOD

Participants and context

The study was conducted in primary school teacher training programs of two Finnish universities (henceforth University A (UA) and University B (UB)). The pre-service teachers (UA: n = 36, 31 female and 5 male, mean age 24.2; UB: n = 18, 16 female, 2 male, mean age 22.6) were participating in a mandatory science methods course. The pre-service teachers took part in an intervention focused on teaching science with simulations as a part of their course. However, the participation to the study was voluntary i.e., they were free to deny the use of their data for research purposes. In both of the interventions the pre-service teachers had to plan and teach science lesson/lessons in groups of 4 to 5 for primary school pupils. The intervention began with a chance for the pre-service teachers to try out different simulations, mainly from the PhET simulation repository (University of Colorado, 2014). During the planning process, the groups had a chance to present their plans to their peers and to their teacher educators. The lessons for each group were carried out in different schools and to different pupils. The interventions lasted for about 2 months with weekly 90 minute meetings.

The main differences between the interventions are presented in Table 1.

Table 1. The main differences between the two interventions.

University	Assignment	Hardware	Software
UA	Plan an inquiry-based science lesson on a given topic	5 laptops per lesson from the university, were known to work	Were given a PhET simulation
UB	Plan a series of science lessons (6 to 10) from any topic, at some lesson simulations had to be used	From the participating schools, were not tested beforehand	Searched and chose their own simulations

Data collection

The data was collected in both universities few weeks after the lessons through a questionnaire. In this study the analysis focuses on the following open items on the questionnaire: “What kinds of possibilities are involved in using simulations in primary school science teaching?” (96 answers in UA, 45 in UB), “What kinds of weaknesses are involved in using simulations in primary school science teaching?” (77 answers in UA, 30 in UB) and “What kind of know-how does a teacher need in order to use simulations in his/her teaching?” (80 answers in UA, 39 answers in UB). The pre-service teachers could list as many answers to each item as they desired. As background questions, items about the pre-service teachers’ previous experiences with simulations were also included. 1 of the 36 pre-service teachers in UA and 1 of the 18 in UB had had previous experiences with simulations in science teaching. They had used them in their high school science lessons.

Analysis

The answers to the items about the possibilities and weaknesses of simulations were analyzed using thematic analysis following the steps by Braun and Clarke (2006). The data was read multiple times in order to be familiarized with it. Then, initial codes for the answers were generated. These codes were then used to form the initial themes which were in the end defined and named.

The answers in the item on teacher know-how were coded using a pre-determined coding scheme based on the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2009; Mishra & Koehler, 2006). The different know-hows listed were coded as either relating to technological knowledge, pedagogical knowledge or content knowledge. These are the main components in the TPACK framework. The coding for the teacher know-how were done by two coders. There was an almost perfect agreement (Landis & Koch, 1977) between the two coders, $\kappa = .913$ (95% CI .851 to .976), $p < .001$. The differences were settled through negotiations. The chi-squared test was used to study the possible differences in the distribution of these three types of know-how between the universities. The alpha level was set at .05.

RESULTS

Possibilities of simulations

Two themes related to the possibilities that simulations bring to science teaching were common to both UA and UB: “demonstrating different phenomena” and “motivating the learners”. The theme “benefits for inquiry learning” was identified just in the answers from UA

Simulations’ ability to visualize phenomena that are otherwise unobservable using our senses was seen as a possibility when teaching with simulations. Answers like “*making abstract things concrete e.g. forms of energy and conservation of energy* (UA)*”* and *“enabling the observation of phenomena which would otherwise be very hard observe in classrooms* (UB)”. Simulations were also seen as visualization tools that support other modes of communication: *“useful tool for demonstrations; supports talk/explanations* (UA)*”, “demonstrates theories exceptionally well* (UB)*”*.

After teaching for the first time with simulations, the pre-service teachers viewed that the learners were motivated to use the simulations. They felt that simulations enable the learners to have an active role in the classroom *“[simulations] prevent the learners from being passive* (UB)*”, “[simulations] inspire to learn* (UB)*”*. Simulations were also seen as motivating for the variety in teaching methods they bring: *“[simulations] are motivating and bring variety to the traditional style of learning with paper and pencil* (UA)*”*.

The pre-service teachers in UA viewed that simulations allow learners to take responsibility of their own learning: *“inquiry learning: raising questions from the learners themselves* (UA)*”*, *“allows the learners to engage in free inquiry* (UA)*”*. Simulations were seen as an effortless learning method to have the learners to engage in inquiry activities: *“(simulations) are an easy way to carry out inquiry teaching* (UA)*”*.

Weaknesses of simulations

The theme “appropriateness of simulations for learning“ was identified as weakness in both UA as well as UB: “appropriateness of simulations for learning“. Only in UA, three additional themes were identified: “need for teacher support”, “too few computers” and “the appearance of the simulations”. For UB, also three additional themes were identified: “effort of finding simulations”, “technical issues of simulations” and “content issues of simulations”.

In both universities the pre-service teachers raised the issue that simulations are not always the best tools for learning science : *“someone might learn better by reading a book, the solution to this is to encourage these learners to pick up their books* (UB)*”*, *“are simulations appropriate* *for the subject, this should be taken into account when planning the lessons* (UA)*"*.The pre-service teachers also feared that simulations could be used too much: *"simulations should not be used too much, I feel that they would lose their purpose* (UA)*"*.

In UA, the need to provide teacher support for learning with simulations was seen as an issue with teaching with simulations: *"the use of simulations requires clarifications and questions essential for learning the content in order to make sure learning is happening* (UA)*"*, *"the learners might act without thinking or realizing their actions, teacher guidance is required* (UA)*"*. Some pre-service teachers were also worried about teachers' ability to tend to the learning needs of many small groups: *"the usage of time by the teacher; does he/she have the time to guide and support the development of every learners' thinking* (UA)*"*.

The issue of having too few computers for the learners and the resulting large group sizes per computer was seen as a weakness in UA. The issue was approached both from the viewpoint of learning: *"group working skills do not necessarily develop if just one from the group uses the simulation and the others are just watching; this could result in less learning* (UA)*"* and from the viewpoint of learning environments: *"The computer class is a gloomy environment; is it possible to get enough computers to a normal classroom to keep the number of learners per computer low?* (UA)*"*.

The appearance of simulations was also seen as a weakness of simulations in UA. It was suspected that simulations are too simple or abstract and these could cause issues for learning: *"[simulations] are radical simplifications of complex phenomena; worst case scenario is that they will cause misconceptions* (UA)*"*, *"the content can be misunderstood if the simulation is not concrete enough* (UA)*"*. The appearance of the simulations was also seen as too primitive: *"appearance really tacky in some cases* (UA)*"*, *"some simulations are kind of crappy; old-fashioned and not working so well* (UA)*"*.

In UB, the pre-service teachers mentioned that the effort to find suitable simulations for the topic at had was too time consuming: *"there are not ready-made simulations always available; at least in the beginning it is tremendous amount of work to find or produce simulations* (UB)*"*, *"it is not easy find simulations for all topics* (UB)*"*.

Technical issues with using simulations were seen as a weakness by the pre-service teachers at UB. Some teachers raised the point that teachers' need to have a plan in case something goes wrong: *"the operation of technological devices and simulations is not guaranteed; that is way there should be some kind of alternative plan in case technology fails* (UB)*"*. Also the need to have s specific kind of device was brought up: *"most of the simulations did not work on a Mac; it is possible that the issue was in the user* (UB)*"*, *"the simulations did not work on all devices* (UB)*"*.

The pre-service teachers in UB felt that the content of some simulations is too difficult for the learners: *"simulations can have sections that do not suit learners of that particular age* (UB)*"*, *simulations are aimed for older learners* (UB)*"*. Pre-service teachers were also not satisfied with some simulations as whole: *"simulations can have a lot of extra content that is irrelevant for learning* (UB)*"*.

Teacher know-how needed to teach with simulations

The teacher know-how listed by pre-service teachers was coded for three different categories of teacher knowledge: content knowledge, pedagogical knowledge or technological knowledge. Teacher know-how related to content knowledge included answers such as *"the teacher must know the content in order to use simulations effectively* (UA)*"*, *"knowledge of content; the* *teacher understands what is happening in the simulation and can point out the essential* (UB)*"*. For pedagogical knowledge the teacher know-how listed included *"organizational skill; the teacher must be able to keep the learners focused on the subject and make them avoid unnecessary messing around* (UA)*"*, *"subtle guiding; making good leading questions* (UA)*"*. Know-how related to technological knowledge included *"ability to solve any possible technological issues* (UA)*"*, *"basic level knowledge of technology* (UB)*"*, *"not much else than then the ability to use technology for benefit and to be critical for its use* (UB)*"*. The absolute and relative frequencies for the different categories of teacher know-how and the chi-square test results for their distributions are presented in Table 2. In UA teacher know-how related to pedagogical knowledge was most common and in UB it was teacher know-how related to technological knowledge. A chi-square test of independence was performed to examine the relation between the interventions and views of teacher know-how. The relation between these variables was significant, χ^2 (2, N = 81) = 6.91, p < .03.

Table 2. Pre-service teachers' views of the teacher know-how needed to teach with simulations.

Type of teacher know-how	University A (n=81)		University B (n=42)		Overall (n=123)	
	frequency	relative frequency	frequency	relative frequency	frequency	relative frequency
Content knowledge	17	21.0%	12	28.6%	29	23.6%
Pedagogical knowledge	39	48.1%	10	23.8%	49	39.8%
Technological knowledge	25	30.9%	20	47.6%	45	36.6%

$\chi^2 = 6.91^*$

DISCUSSION AND CONCLUSIONS

Results common for both universities

The teachers both in UA and UB felt that possibilities of using simulations in science teaching lie in their ability to demonstrate different phenomena and to motivate students to learn science. Previous research on simulations has acknowledged the possibilities that simulations have regarding learning about phenomena and situations that are otherwise e.g. too slow to observe (van Berkum & de Jong, 1991). The motivational benefits of simulations compared to traditional lectures have also been verified in many studies (Rutten et al., 2012). By participating in this kind of short intervention and teaching a lesson using simulations, the pre-service teachers were able to form beliefs that are empirically valid and in unison with the research literature on the subject.

Regarding the weaknesses of simulation in science teaching, pre-service teachers from both universities felt that simulations are not always useful tools for teaching specific content. Some learners prefer other learning methods and the teacher must pay attention to how using simulations would benefit the learning of any specific content. This conception about simulations in science teaching is shared by the research community. Although some studies find that learning specific content with simulations results in better conceptual learning than traditional hands-on activities (Zacharia, 2007; Zacharia, Olympiou, & Papaevripidou, 2008), other studies find that the best learning results come from combining hands-on activities and simulations (Jaakkola & Nurmi, 2008). Also, the interaction with physical manipulatives is beneficial for learning e.g. the complexity to collect scientific evidence (Zacharia & Constantinou, 2008). Even though the intervention was about using simulations to teach science, the pre-service teachers were able to form a critical belief backed up research literature that simulations are not the best teaching tools for everything in science.

The pre-service teachers saw that teachers need mainly know-how related to pedagogical and technological knowledge when teaching science with simulations. The high number of answers related to technological knowledge implies that the pre-service teachers think about teaching science with simulations to be about the technology per se, not what kinds of possibilities and challenges it imposes on the teachers. The connection between self-assessed technological knowledge and attitude towards simulations has been discovered in previous research (Lehtinen, Nieminen, Viiri, 2015). The role of the teacher in supporting the learners in working with the simulations from a pedagogical, not technological standpoint, is seen as critical for the integration of simulations in science classrooms (Hennessy, Deaney, & Ruthven, 2006; Smetana & Bell, 2012). Maybe through more experience in teaching with simulations the pre-service teachers would gain a better view on the pedagogical teacher know-how needed in teaching with simulations.

Differences in results between the universities

The pre-service teachers in UA were assigned to plan and teach an inquiry-based lesson in which simulations were used. Also the theme “benefits for inquiry learning” was identified in their answers about the possibilities of simulations. Because the assignment in UB did not involve an inquiry-based lesson and a similar theme was not identified from their answers, we feel it is justified to argue that assigning the pre-service teachers to plan and teach an inquiry-based lesson affected their view on the possibilities of simulations.

Regarding the weaknesses of simulations, in UB the pre-service teachers felt that the effort to find the simulations to use was a weakness of using simulations alongside with technical issues and issues with the content of the simulations. In UB the pre-service teachers could choose the topics of their lessons to be taught and also the simulations that they used in them. They also did not have a chance to try out the actual hardware they used in their lessons beforehand. This was in contrast with UA, where they pre-service teachers were given a simulation to use and a topic to plan the lesson about. They also could use hardware from the university itself which was known to work with the simulations. We argue that the weaknesses of simulations identified only in UB and not in UA can also be explained with differences in the interventions. It was the first time using simulations for almost every pre-service teacher from UB. That means that they had for the first time look for these simulations from the internet and other sources. This would explain the theme identified weakness “effort of finding simulations”. They also had to rely on their own, most probably quite limited, experience in teaching science to choose the proper topic and simulation for the intended age group of the learners. It is possible that they chose too difficult simulations for the grade they were teaching in and thus felt that there were issues with the content of the simulations. Some of them explicitly mentioned the content of the simulations being too difficult for the learners. The fact that the pre-service teachers in UB were not able to tests their simulations on the schools’ hardware before teaching the lesson and the fact that the theme “technical issues of simulations” was identified in their answers implies that at least some of them experienced some technical difficulties in using the simulations.

For the teacher know-how needed to teach science with technology there was a statistically significant difference in the distribution of the types of teacher know-how between the two universities. The pre-service in teachers in UB viewed the teacher know-how needed as more relating to technological knowledge and less to pedagogical knowledge than the pre-service teachers in UA. The possible technological difficulties that the teachers in UB experienced can explain this. In order to teach with simulations and to think about pedagogical factors affecting their use, the simulations need to function technically. If the pre-service teachers in UB were faced with technological issues when using the simulations, they were more focused in getting them to work than in the actual teaching. The experience of having to deal with technological issues using simulations could affect their perception of the needed teacher know-how when using simulations.

Possible limitations

The results of this study are generalizable to the population of pre-service primary teachers but as shown in this paper the differences in these types of interventions affect the pre-service teachers' beliefs. Following another kind of intervention the beliefs could be different. The data was collected through questionnaire items that were narrowed down. A more open type of data e.g. interviews could have brought an extra perspective to the analysis.

Conclusions

The conclusions of this study support the Interconnected Model of Professional Change; external stimulus (in this case the simulation intervention) has an effect of pre-service teachers' beliefs. In this study, this was most evident in the perceived weaknesses of simulations and on the teacher know-how needed to teach science with simulations.

What does this mean for teacher education related to teaching science with simulations? Because the connection of beliefs related to technology and successful technology integration in classrooms has been uncovered in recent research (Ertmer et al., 2012; Kim et al., 2013), attention to them must be paid in order to efficiently train future science teachers. This study shows the importance of carefully designing teacher training relating to the educational uses of technology. Ideally, the pre-service teachers would have a true and correct perception of their future work as teachers after finishing their teacher training. When teaching with simulations is concerned, that work includes some effort to find and choose fitting simulations for the topics to be taught with simulations. Also sometimes there can be technical difficulties when using simulations, as with all technology. This study shows that if pre-service teachers are faced with these situations as a part of their teacher training, it affects their beliefs related to teaching with simulations. After graduating, if a teacher beliefs that using simulations is hard work and there might be technical problems with using them, she/he might decide to not use simulations at all. Research shows that even if teachers are aware of the learning benefits of technology, their beliefs about technology can still affect their technology integration practices (Ertmer, 2005). Incremental supports are needed (Kim et al., 2013) throughout teacher training to facilitate technology integration in education and the technological confidence of pre-service teachers should be increased as a part of pre-service teacher education (Ertmer, 2005). It might be difficult to find the right balance between giving too much and too little support for pre-service teachers in teaching with simulations but it is something that future research could strive for.

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III

GUIDANCE PROVIDED BY TEACHER AND SIMULATION FOR INQUIRY-BASED LEARNING: A CASE STUDY

by

Lehtinen, A., & Viiri, J., 2017

Journal of Science Education and Technology, 26(2), 193-206

J Sci Educ Technol (2017) 26:193–206
DOI 10.1007/s10956-016-9672-y

Guidance Provided by Teacher and Simulation for Inquiry-Based Learning: a Case Study

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Abstract Current research indicates that inquiry-based learning should be guided in order to achieve optimal learning outcomes. The need for guidance is even greater when simulations are used because of their high information content and the difficulty of extracting information from them. Previous research on guidance for learning with simulations has concentrated on guidance provided by the simulation. Little research has been done on the role of the teacher in guiding learners with inquiry-based activities using simulations. This descriptive study focuses on guidance provided during small group investigations; pre-service teachers ($n = 8$) guided third and fifth graders using a particular simulation. Data was collected using screen capture videos. The data was analyzed using a combination of theory- and data-driven analysis. Forms of guidance provided by the simulation and by the teachers were divided into the same categories. The distribution of the guidance between the teacher and the simulation was also analyzed. The categories for forms of guidance provided by simulations proved to be applicable to guidance provided by the teachers as well. Teachers offered more various forms of guidance than the simulation. The teachers adapted their guidance and used different patterns to complement the guidance provided by the simulation. The results of the study show that guidance provided by teachers and simulations have different affordances, and both should be present in the classroom for optimal support of learning. This has implications for both teaching with simulations and development of new simulations.

Keywords Simulations · Educational technology · Inquiry-based learning · Guidance · Scaffolding

Introduction

Computer simulations used in science teaching can be defined as a computer program that mimics the behavior of a real system (de Jong and Lazonder 2014). They can be used to investigate scientific phenomena as a part of inquiry-based science teaching (de Jong 2006b). Simulations offer a chance for learners to perform experiments by changing variables and observing the effects. Research on inquiry-based learning indicates that learners need support to overcome difficulties with certain tasks, such as drawing conclusions from data (Alfieri et al. 2011). Support or guidance for inquiry-based learning can come from different sources, including the simulation or accompanying software, the teacher, or other learning material. Thus far, the research on supporting inquiry-based learning with simulations has concentrated on the guidance provided by the simulations or by the accompanying software, and the teachers' role in guiding learners has not received much attention (Smetana and Bell 2012). The aim of this descriptive study is to describe the forms of guidance provided by teachers and a particular simulation for learning about balance at the primary education level. Using the same categorization for the guidance provided by teachers and the simulation enables the study of forms of guidance provided by these two sources. Different patterns for the distribution of guidance highlight the complexity of providing guidance for inquiry-based science learning with simulations.

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Literature Review

Inquiry-Based Learning and Simulations

Computer simulations can enhance traditional (i.e., lecture-based, textbook-based, and/or practical work) science instruction (Rutten et al. 2012; Smetana and Bell 2012). The simulations should be integrated with other classroom activities and used in a way that allows the learners to have an active role in the investigation (Rutten et al. 2015; Smetana and Bell 2012). This conforms with the consensus in science education that learners should be engaged in inquiry, experimentation, and discovery as active agents and simultaneously develop their practices related to science (de Jong and Lazonder 2014; National Research Council 1996; National Research Council 2000; NGSS Lead States 2013). Inquiry-based learning is usually defined through phases or features of inquiry starting with asking questions or generating hypotheses, moving on to conducting investigations and drawing conclusions from the collected data, and finally communicating these conclusions to others (Bell et al. 2010; National Research Council 1996; National Research Council 2000). In order to identify and summarize the core features of inquiry-based learning, Pedaste et al. (2015) conducted a systematic literature review of the existing literature on inquiry-based learning. The result is an inquiry cycle consisting of five phases: stimulating interest (orientation), stating theory-based questions and/or hypotheses (conceptualization), planning and carrying out investigations (investigation), drawing conclusions based on the data (conclusion), and communicating the information to others and reflecting on one's own actions (discussion). This paper uses Pedaste et al.'s definition of inquiry since it is based on earlier definitions of inquiry and has already been used to study guidance provided by simulations for inquiry-based learning (Zacharia et al. 2015).

Guidance for Inquiry-Based Learning

Inquiry learning can be unguided or guided. In unguided inquiry learning, the learners are fully in control of the whole inquiry learning process; in guided inquiry, the teacher or some other source (e.g., a simulation) provides support for the process (Furtak et al. 2012). Unguided inquiry learning has been criticized as ineffective and cognitively too challenging for learners (Alfieri et al. 2011; Kirschner et al. 2006; Mayer 2004). In inquiry-based learning, learners may have issues with generating suitable hypotheses, with designing experiments, and with drawing conclusions and/or regulating their own learning process (de Jong and van Joolingen 1998; de Jong and Lazonder 2014). These issues may be exacerbated by the use of simulations instead of physical, hands-on experiments. This is because the high information content of simulations and the difficulty of extracting information from them (Zacharia et al. 2015) increases the need for meta-cognitive skills (Hegarty 2004). Empirical research on inquiry learning has shown that providing assistance—e.g., feedback, worked examples, or elicited explanations during the inquiry learning process—benefits learners and improves learning outcomes (Alfieri et al. 2011). In general, guidance for inquiry learning should be personalized (i.e., adapted to the learners' knowledge and skills), fade away (i.e., the amount of guidance should decrease during the learning process), and support self-regulated learning (de Jong and Lazonder 2014).

Guidance for inquiry learning can be classified in different ways, such as by the phase of the inquiry cycle it addresses (de Jong 2006a) or by the learning process it supports (Quintana et al. 2004). De Jong and Lazonder (2014) developed a typology that organizes different forms of guidance according to their levels of specificity. Table 1 lists these forms of guidance and an example of each form. The issues with the terms *guidance*, *scaffolding,* and *scaffolds* become apparent here. The first two terms are often used to describe the same thing, a type of support designed to promote learning, and the term *scaffolding* focuses on responsiveness to learners' actions (van de Pol et al. 2010). *Scaffolds,* on the other hand, are one form of guidance in the classification by de Jong and Lazonder (2014). In this paper, we use the term *guidance* to describe all support designed to promote learning.

Zacharia et al. (2015) reviewed the existing research on guidance for inquiry learning using virtual laboratories (i.e., simulations) and online laboratories. This review only addressed guidance provided by the computer software—the simulation or accompanying software. This is a general trend in research on support for learning with simulations; most previous research has focused on the instructional support provided by the simulation itself (Rutten et al. 2012). However, the role of the teacher when using simulations in science education is a critical element in their successful implementation (Hennessy et al. 2006; Rutten et al. 2015; Smetana and Bell 2012). It is still unknown what sort of guidance teachers can offer for learning science with simulations (Chang 2013; Rutten et al. 2012; Smetana and Bell 2012).

Although this paper thus far has contrasted guidance provided by the software and the teacher, these two types of support can co-exist and interact with each other. Key factors of successful guidance are the same no matter who or what provides it; van de Pol, Volman, and Beishuizen (2010; 2012) list the same three characteristics (i.e., adaptation to the learner, fading out, and support for self-regulated learning) for scaffolding in teacher-learner interaction as de Jong and Lazonder's (2014) list for guidance provided by the software in inquiry learning.

Table 1 Forms of guidance for inquiry learning with simulations (de Jong and Lazonder 2014)

Form of guidance	Description	Example
Process constraint	Reduces the complexity of the learning process by limiting the number of options	Model progression segments the simulation into parts which differ from one another by their complexity and type of representation (Veermans 2003)
Performance dashboard	A real-time progress report of the learning process or evolving knowledge	The SIMQUEST monitoring tool enables the learners to review and replay their experiments (van Joolingen and de Jong 2003)
Prompts	Reminders to carry out certain actions or learning processes	Prompts for self-reflection for the whole inquiry process (Eckhardt et al. 2013).
Heuristics	Suggestions on how perform a certain action or learning process	VOTAT—vary-one-thing-at-a-time (Veermans et al. 2006)
Scaffolds	Tools that help learners perform a learning process by structuring the activity	Hypothesis scratchpad that helps learners produce a hypothesis by selecting variables to fill "if-then" statements (de Jong 2006a)
Direct presentation of information	Giving out target information if the learners are unable to discover it on their own	An argumentation palette that enables the learners to compare their conclusion to an expert conclusion (de Jong 2006a)

Teachers and software have different capabilities to provide guidance. For example, teachers can obtain information about learner performance from different sources than software (Ruiz-Primo 2011). This affects their ability to adapt guidance to learner needs. Puntambekar and Kolodner (2005) use the term *distributed scaffolding* to describe instructional designs that include guidance from multiple providers (e.g., the software and the teacher). Distributed scaffolding can follow one of three different patterns (Tabak 2004). The first pattern is a *differentiated scaffold.* In this pattern, each of the learners' different needs is addressed by a specific form of guidance. The goal in implementing this pattern is to identify the form of guidance that is best suited to a specific learning need. The second pattern is that of *redundant scaffolds;* in this pattern, multiple forms of guidance target the same need, but they are enacted at different points in time. The redundancy of guidance ensures that all learners benefit from at least some of the different forms of guidance. The third and final pattern is that of *synergistic scaffolds.* In this pattern, multiple forms of guidance co-occur and interact with each other. The rationale behind this pattern is that some skills and practices embody such a wide array of knowledge and values that multiple forms of support must be used in unison to support the development of such skills and practices.

Guidance for inquiry-based learning is a complex process that encompasses multiple forms and providers of guidance and multiple patterns distributing guidance between these providers. The objective of the present descriptive study is to investigate guidance provided by both the software and teachers in the context of one particular simulation and topic. The decision to concentrate on just one simulation was based on the fact that simulations and their surrounding frameworks differ from one simulation to another (Clark et al. 2009). The results add to the literature on how teachers provide guidance for learning science with simulations in this particular case and how teachers' guidance can be contrasted with the guidance provided by the simulation. The same categorization was used for guidance provided by the simulation and by the teachers so these two sources could be contrasted. Through examples of different patterns for distributed guidance, this study aims to highlight the complexity of providing guidance for inquiry-based learning with simulations.

Our research questions are as follows:

1. What forms of guidance does the Balancing Act PhET simulation provide?
2. What forms of guidance do pre-service teachers provide when guiding learners working with the Balancing Act PhET simulation?
3. How do different patterns for distributed guidance manifest when teaching with the Balancing Act PhET simulation?

We acknowledge that there could be differences in the ability of pre-service and in-service teachers to guide learners. This study describes the guidance provided for inquiry-based learning by pre-service teachers and by one particular simulation adding to the literature on the role of the teachers in general in guiding inquiry-based learning with simulations. Pre-service teachers might guide learners differently than in-service teachers, but both play the same role in lessons as human facilitators of learning. By contrasting the guidance provided by pre-service teachers with guidance provided by the simulation, this paper also contrasts guidance provided by humans with that provided by the simulation.

Method

The data for the study comes from a larger project in which pre-service primary teachers (PSTs) participated in an intervention (Lehtinen et al. 2016) aimed at improving their skills and confidence in teaching inquiry-based physics with simulations. At the end of the intervention, the pre-service teachers planned and taught an inquiry-based physics lesson for primary-aged learners using a predetermined simulation. The lessons were planned and taught by groups of five PSTs. The data for this study comes from these two lessons (45 min each); the topic was learning about balance using a seesaw. The lessons were taught to a third-grade class with 15 learners and a fifth-grade class with 13 learners. Each of the two lessons was planned and taught by two different groups of five PSTs each. These two groups of PSTs were told to implement the given simulation in an inquiry-based lesson, and they planned the lessons independently. The simulation used in these lessons was the *Balancing Act* simulation from the PhET website (University of Colorado Boulder 2016). This particular simulation was chosen for this case study because of its high amount of embedded guidance compared to most PhET simulations. Even though the two participating classes were from different grades, there was no significant difference in the level of content of the two lessons. The main difference between the two lessons was in the approach to drawing conclusions based on the investigations. Fifth-grade learners were given a handout and asked to fill in the variables that affect the balance of the seesaw and the rule that allows it to balance; the learners had to deduce these answers from their investigations. Since third-grade learners are less able to write conclusions than are fifth graders, they expressed their conclusions verbally to the PST guiding their group. Both classes followed the standard Finnish science curriculum, and both classes had not received instruction on balance before the study.

Both of the lessons followed the basic phases of inquiry-based instruction (Pedaste et al. 2015): the PSTs started the lessons by stimulating the learners' interest and connecting the forthcoming experiment with their everyday experience by asking the learners about their playground experiences with seesaws. One or two of the five PSTs conducted the orientation, and the others observed. The learners knew from experience that if two people want to balance a seesaw, the lighter one has to sit further from the fulcrum. In order to quantitatively examine the connection between the ratios of weights and distances from the fulcrum, the learners used the simulation to investigate the phenomenon in groups of three to five. The data analyzed in this paper comes from this investigation phase of inquiry. Each of the five PSTs guided one group of learners in their investigations. The PSTs were focused on letting the learners work on their own but guided them in collecting data and drawing conclusions from it. As they went through the simulation, the learners came up with initial ideas about the ratio of weights and distances from the fulcrum, which they could then apply to the assignments embedded into the simulation. After the investigation, one of the PSTs led a discussion as the learners shared their findings with other groups; the PST also asked the learners to reflect on the lesson and the inquiry.

Participants

The participants of the study were Finnish pre-service primary teachers ($n = 8$) (PSTs A to H). They ranged in age from 20 to 31 (M = 24.9, SD = 3.8), and they had 6 months to 2 years of previous general teaching experience. None of the pre-service teachers had any experience in teaching science with simulations, and all of them were taking a science teaching methods course in the same semester the lessons were taught. The PSTs majored in special education, but they had chosen primary teacher studies as their minor. Of the ten pre-service teachers who planned and taught the lessons, one PST was left out of the study due to missing research permits from the learners, and one PST was left out because of outside interference during his/her teaching. Informed consent was obtained from all individual participants in the study.

Data

Each small group consisting of three to five learners was given a laptop in which the simulation ran. Their experiments with the simulation and the talk between the learners and the teacher were recorded using screen capture software running on these laptops. The laptops' inbuilt microphones recorded the talk. The lessons were also recorded using two stationary cameras at the front and back of the classrooms. The screen capture video data consisted of around 200 min of experimentation with the simulation from eight groups of three to five learners and a pre-service teacher guiding them. The analysis for the teachers' guidance was done through the screen capture videos.

Analysis of the Guidance Provided by the Simulation

The Balancing Act simulation (University of Colorado Boulder 2016) is aimed at learners in primary and lower secondary schools and deals with balance and torque. The interface of the simulation is pictured in Fig. 1. The simulation is divided into three tabs: Intro, Balance Lab, and Game. In the Intro tab, the users can experiment with the seesaw using three objects. Two of the objects weigh 5 kg and one weighs 10 kg. The seesaw's supports can be removed and replaced. The masses of the objects, the forces they exert, the positions of the objects on the seesaw, and the level meter can be hidden or shown. The Balance Lab tab allows the users to put more than three objects on the seesaw. In this tab, the relative weight of

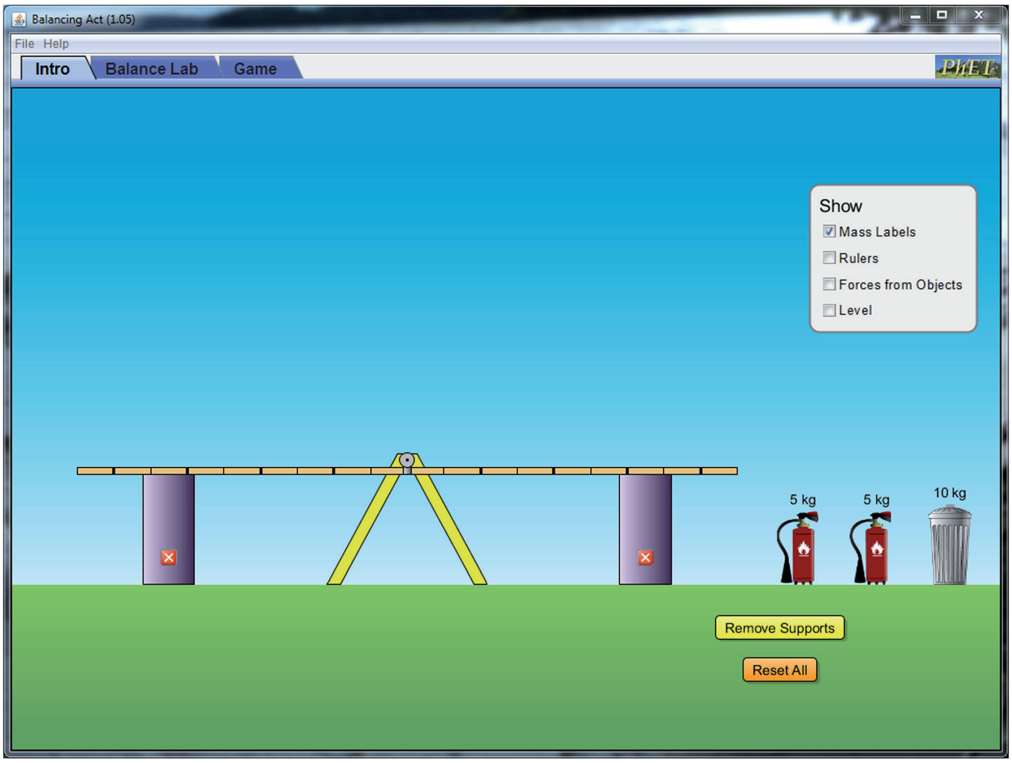

Fig. 1 The interface for the Intro tab of the Balancing Act simulation

the objects does not have to be 1:2. The Balance Lab also allows so-called mystery objects of unknown weight to be put on the seesaw. Finally, in the Game tab, the users can choose assignments from four different levels of difficulty. These assignments challenge the users to apply the knowledge gained from the two previous tabs. The assignments include, for example, placing an object so that the seesaw is balanced or finding the weight of an object by using it to balance the seesaw. Users receive points for successfully completing an assignment (2 points = correct answer on the first try, 1 point = correct answer on the second try; after two attempts, the user gets 0 points and the correct answer is shown).

To classify the guidance provided by the Balancing Act simulation, it was compared to a hypothetical, unguided version of the same simulation. In such a sandbox-like simulation, learners would be presented with just a seesaw and objects of varying weights to place on the seesaw; there would be no structure or feedback from the simulation. This would mirror the same experiment conducted in a traditional, physical, hands-on method; then, the structure and guidance must come from other sources. All features found in the actual Balancing Act simulation and not the hypothetical, unguided version (e.g., the option of showing and hiding the objects' weights and the assignments in the Game tab) were each scrutinized for their possible role in guiding the learners in their experimentations. The term *guiding element* is used to describe the features of the simulation that guide learners in their investigations. The guiding elements of the simulation were into categorized typology developed by de Jong and Lazonder (2014). For example, the assignments embedded into the simulation in the Game tab were seen as guiding elements and categorized as prompts.

Analysis of the Guidance Provided by the Teachers

The conversation between the learners and the pre-service teachers was analyzed in order to categorize the guidance provided by the teachers into the forms defined by de Jong and Lazonder (2014) as well. The analysis had two main phases. The first phase involved coding the transcribed discussions between the teachers and learners into six categories, forms of guidance. De Jong and Lazonder's (2014) descriptions of the forms of guidance and Zacharia et al.'s (2015) examples from previous research on different forms of software guidance were used. The term *guiding action* is used to describe each action of guidance provided by the teachers. The length of these guiding actions ranged from single utterances to discussions lasting around 3 min. A total of 421 guiding actions were identified in the data. De Jong and Lazonder's descriptions and Zacharia et al.'s examples of each form of guidance were scrutinized to identify the factors in each form of guidance that are not unique to guidance provided by simulations. These factors were then used to code the transcripts of the guiding actions. One example is the performance dashboards provided by the teachers. Even though the teachers could not verbally give the learners a visual dashboard the way that the software can, they could still give the learners real-time progress reports about their learning process and knowledge status. This type of guiding action fits de Jong and Lazonder's description of performance dashboards.

The second phase used thematic analysis (Braun and Clarke 2006) to more accurately describe the guidance provided by the teachers. The timing, content, and possible connection to previous events of each guiding action were scrutinized when defining and naming the themes. For guiding actions in the form of performance dashboards, prompts, and heuristics, two different themes were defined for each. These themes act as subcategories for those forms of guidance. The subcategories differ not in the specificity of guidance provided but in their timing, content, and connection to previous events.

An inter-rater reliability analysis using Cohen's Kappa was performed to establish consistency between two raters. The first author coded all of the data, and the second author coded a subset of the data using a coding manual. Regarding discerning teachers' guiding actions from non-guiding actions, the second author coded 10% of the data. The percentage of agreement between the authors was 96%, and $\kappa = 0.897$ (95% CI from .721 to 1), $p < .0005$. For the different forms of guidance, the second author coded 15% of the data, and the percentage of agreement was 88%, and $\kappa = 0.798$ (95% CI from .675 to .904), $p < .0005$. When the subcategories for performance dashboards, prompts, and heuristics were taken into account, the percentage of agreement was 83%, and $\kappa = 0.784$ (95% CI from .664 to .883), $p < .0005$. These values indicate a fine reliability for high-inference coding of the video data in this study (Fischer and Neumann 2012).

Analysis of the Distribution of the Guidance Provided by Different Sources

The analysis of the distribution of guidance revolved around the interaction of guidance provided by different sources and the temporal properties of the guidance (Puntambekar and Kolodner 2005; Tabak 2004). We examined the interaction of the simulation's guiding elements with the teachers' guiding actions and vice versa, also considering the learning need that each guiding element or action supports. Examples for each pattern of guidance as defined by Tabak showcase the complex nature of guiding inquiry-based learning with simulations via multiple sources of guidance.

Results

Guidance Provided by the Simulation

Table 2 provides an overview of the forms of guidance provided by the Balancing Act simulation. No heuristics or scaffolds were present in the simulation.

Three different elements of process constraints were present: *progression within the simulation, progression within the Game tab,* and *visualization settings*. The simulation is divided into three tabs (see Figs. 1 and 2), and the learner can be expected to progress through the tabs in the order they are presented. This progression ensures that the learners first try to balance the seesaw in a simple situation with fewer variables before moving on to a more challenging situation and finally applying their skills to the assignments in the Game tab. Within the Game tab, the simulation offers four different levels of assignments. The levels differ; for example, the number of objects on the seesaw changes from one level to the next, as do the objects' weight ratios and distances from the fulcrum. This progression also allows learners to first apply their skills to simpler situations and then move on to more challenging ones. As the final process constraint, the distances of the objects from the center of the fulcrum and the forces they exert on the seesaw are hidden on default but can be shown. The default settings simplify the simulation and hide information away that could distract the learners in the beginning of their experimentations. As the learners' knowledge increases, these settings can be enabled.

The *score* given to the learner based on the number of attempts they need to complete the assignments in the Game tab is a kind of performance dashboard. The score gives learners real-time information about their level of knowledge and their progression. As the learners gain knowledge, they are able to answer more of the assignments correctly on the first try, increasing their score. The *assignments* themselves are also a form of guidance. They serve as prompts which enable the learners to apply their knowledge. Because the assignments are preceded by the two other tabs, the learners have had a chance to develop the necessary knowledge needed to complete the assignments. Finally *giving the learners the correct answer* to the assignments after two incorrect answers serves as a form of direct presentation of information. Revealing the answer ensures that learners

Table 2 Forms of guidance and guiding elements from the Balancing Act simulation, with their descriptions

Form of guidance	Guiding element	Description
Process constraint	Progression within the simulation	Each subsequent tab presents more options to the learners enabling more complex situations to be studied.
	Progression within the Game tab	Four different levels of assignments give learners a chance to progress to more difficult assignments.
	Visualization settings	The distances of the objects from the fulcrum of the seesaw and the exerted forces are hidden by default but can be shown at will.
Performance dashboard	Score	Points given in the Game tab give information to the learners about their skills and knowledge.
Prompts	Assignments	Assignments in the Game tab prompt the learners to apply their skills and knowledge.
Direct presentation of information	Giving the correct answer	The correct answer to the assignments in the Game tab is shown after two wrong answers.

who are unable to answer an assignment can still benefit from the content information implicitly embedded in the correct answer and use this knowledge to progress through the rest of the assignments.

Guidance Provided by the Teachers

Table 3 provides an overview of the forms of guidance provided by the pre-service teachers.

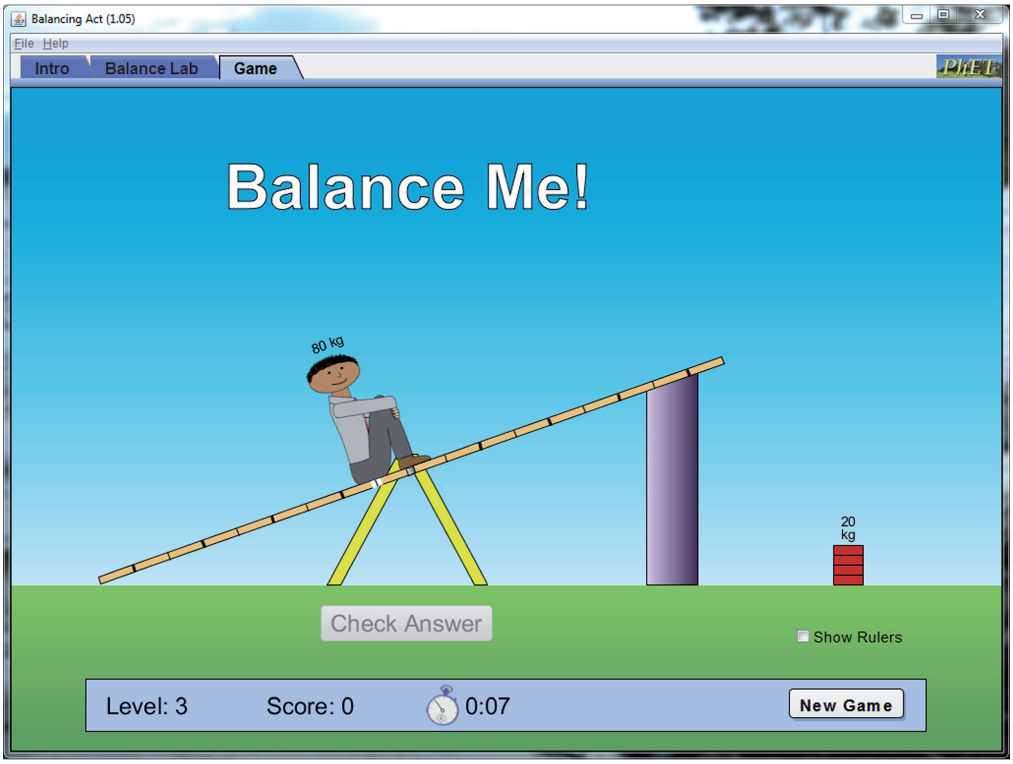

Fig. 2 An example assignment from the Game tab of the Balancing Act simulation

Table 3 Forms of guidance and guiding actions provided by the pre-service teachers, with their descriptions

Form of guidance	Guiding action	Description
Process constraint	Reducing options	Suggestion to the learners to, e.g., use just two objects or hold an object in its place
Performance dashboard	Feedback on experimentation	Feedback for the learners as they experiment with the simulation on e.g. good strategy for experimenting with the simulation
	Feedback on answer	Feedback for the learners after they have answered to an assignment or have succeeded in an assignment given by the teacher
Prompts	Prompt for action	Prompt to perform an action with the simulation, e.g., to complete an assignment from the Game tab or to balance the seesaw in a given situation
	Prompt for answer	Prompt to give a verbal response, e.g., to set up a hypothesis or reflect on their actions
Heuristics	Reminder	Reminder about a previous assignment or the rule which they can use to balance the seesaw
	Hint	A hint to the learners which gives them information needed to balance the seesaw or complete an assignment
Scaffolds	Dividing the problem into smaller parts	Investigation into the similar ratios of weights and their distances from the fulcrum is structured by asking multiple simple closed questions in a row
Direct presentation of information	Presentation of information	Presenting the learners with, e.g., the rule by which the seesaw can be balanced with or the factors (weight and distance from the fulcrum) that affect the balance

The different forms of guidance provided by the pre-service teachers are presented in the following sections through illustrative examples and excerpts from classroom dialog.

Process Constraints by the Teachers

The pre-service teachers used process constraints when the learners were overwhelmed by the number of options (number of objects, places for the objects, etc.). This excerpt illustrates one of these situations. In the excerpt, the learners are trying to balance the seesaw in the Intro tab with two fire extinguishers (weighing 5 kg each) on one side and one trash bin (weighing 10 kg) on the other side. The pre-service teacher (PST A) sees that the learners have already tried to move the objects into different places and are having difficulty balancing the seesaw.

> PST A: Well, now we notice that the side with the fire extinguishers still weighs a bit more—let's do it like this: let's keep the trash bin where it is now; let's agree we'll not move it anymore [Process constraints]. Then, how could we make the side with the fire extinguishers a bit lighter?
> Learner 1: If we would put them a bit forward.
> PST A: Yeah, you can put them forward.

PST A suggests that the learners leave the trash bin in place and only adjust the place of the fire extinguishers on the other side of the seesaw. By doing so, PST A removes a degree of freedom from the assignment, reducing the complexity of the situation. Thus, this guiding action restricts the number of options the learners have to consider, which is characteristic of a process constraint (de Jong and Lazonder 2014).

Performance Dashboards by the Teachers

Even though the pre-service teachers were not able to present real-time information to the learners via a visual dashboard, they still gave the learners feedback about their learning process and the quality of their outcomes. This feedback was given in two different types of guiding actions. First, the pre-service teachers gave the learners feedback while they experimented with the simulation. This feedback occurred when the learners were close to balancing the seesaw or when they utilized a good strategy in their experiment. Second, the teachers gave feedback on, e.g., the good quality of the learners' explanations of the phenomena after the learners had completed an assignment. In the following excerpt, the pre-service teacher (PST B) gives feedback during experimentation. The learners are working on an assignment from the Game tab of the simulation. The assignment asks the learners to determine the weight of an unmovable vase by using another object weighing 5 kg to balance the seesaw.

> Learner 3: Should we put it there?
> Learner 4: Put it there.

> L 3: Try it first all the way in the end.
> L 2: Hey put it there, because then it's it the same spot as the other one.
> *[The learners put the object in the same spot as the vase but on the other side of the seesaw. The seesaw balances.]*
> PST B: That was a very good idea to try it first in the same spot [Performance dashboard—feedback on experimentation]. Well, what can you now deduce from this situation?
> L 2: That would be five kilos.

In this excerpt, PST B praises Learner 2 for his/her strategy for the assignment. The learner suggests placing the object with a known weight at the same distance from the fulcrum as the vase, the weight of which is unknown. Seeing what happens then tells the learners whether the unknown weight is less than, more than, or the same as the known weight. The pre-service teacher explicitly states that this particular strategy is a good idea, which gives the learners information about their learning process and knowledge. The learners can act on the feedback, which is an essential characteristic of a performance dashboard that provides guidance (de Jong and Lazonder 2014).

Prompts by the Teachers

The pre-service teachers prompted the learners in two different ways. First, they prompted the learners to interact with the simulation—for example, to balance the seesaw in a given situation in the Intro and Balance Lab tabs or to complete an assignment in the Game tab. These actions caused the learners to apply their knowledge to balance the seesaw or complete the assignment. Second, the teachers prompted the learners for verbal responses. They instructed the learners to form hypotheses before trying to complete an assignment and prompted them to reflect on their actions and answers. The excerpt below shows pre-service teacher C (PST C) prompting the learners to reflect on their actions after completing an assignment in the Game tab. In this assignment, the learners had to balance the seesaw using a weight of 20 kg on one side with a fixed weight of 10 kg on the far end of the other side.

> Learner 5 *[talking to Learner 6, who is using the simulation]*: So, put it there—no, wait, one step forward—that's it. Let us see if it's correct.
> *[The 10-kg weight is placed half as far from the fulcrum as the 20-kg weight, but on the other side. The seesaw balances, and the simulation informs the learners of their correct answer.]*
> PST C: Yeah.
> L 5: It was.
> *[Learner 6 moves the mouse cursor to the "Next" button.]*
> PST C: Do not go on to the next assignment yet—what was the reason that this was the correct answer? [Prompts—prompt for answer]
> L 5: Well, wait a minute...
> Learner 6: The 20-kg weight a bit heavier but….
> Learner 7: Which means it's more to the center.

In the excerpt, the learners succeeded in balancing the seesaw on their first attempt. They are ready to move on to the next assignment, indicated by moving the cursor to the "Next" button. At this point, PST C prompts the learners to explain why their answer was correct. The discussion that follows was initiated by this prompt, and it probably would not have happened without it. The prompt served as a stimulus for the learners to reflect on their answer when they did not show initiative to do so on their own, which fits the description of prompts (de Jong and Lazonder 2014).

Heuristics by the Teachers

The pre-service teachers guided the learners using two different types of heuristics. The first type of heuristics involved reminding the learners of something they had previously done. This could include a reminder of a similar assignment in the Game tab or a reminder of a rule they had previously formulated for balancing the seesaw. The second type of heuristics involved giving the learners a hint. These hints pointed out possible actions or ways to perform the action. In the excerpt below, a pre-service teacher (PST A) uses both types of heuristics. The learners are working on an assignment in the Game tab in which they must determine the weight of a trash can, which is fixed in one place on the seesaw, by balancing the seesaw using a brick that weighs 15 kg.

> Learner 1: Now this trash can.
> PST A: This is a similar assignment to the one where you had to guess the weight [Heuristics—reminder].
> L 1: Maybe it's ten kilos in this one as well… probably not.
> PST A: I think you should first put it so that the seesaw balances itself; try it [Heuristics—hint].
> Learner 8: Put it all the way to the end.
> L 1: Oh, yeah. OK.
> *[The brick is placed to the far end of the seesaw. The seesaw balances.]*

In the excerpt, PST A pointed out that the assignment at hand is similar to an earlier assignment, which the learners had already completed. This guiding action served as a reminder. It directed the learners' thoughts toward the previous assignment and how they completed it. This is a characteristic of heuristics (de Jong and Lazonder 2014). Learner 1 begins to think aloud about the possibility that the answer to this assignment is the same as that of the previous assignment which PST

A referred to. It was not clear to the learners that in a similar assignment, same-looking objects could have different weights. This may have spurred PST A to give a hint on how to proceed with the experiment; the teacher hinted that they should first try to find a position for the brick which balanced the seesaw. This guiding action serves as a heuristic because it points out a way to complete a task (de Jong and Lazonder 2014).

Scaffolds by the Teachers

De Jong and Lazonder (2014) define scaffolds as tools that structure the activity. Instead of tools, the pre-service teachers provided scaffolds by dividing the process of drawing conclusions from the experiments into smaller steps, providing a structure for drawing conclusions. The pre-service teachers asked multiple closed questions about the ratio of weights and their distances, which provided the learners with the components of the process. The questions structured the learning process and thus simplified a complex process, which fits the description of scaffolds by de Jong and Lazonder. In the following excerpt, a pre-service teacher (PST D) provides this kind of guidance. In the excerpt, the learners are working on an assignment from the Game tab in which they must predict what will happen when the supports are removed from a seesaw that has two bricks weighing 5 and 15 kg on opposite sides of the seesaw at the same distance from the fulcrum. The simulation gives them three options: the seesaw tilts to the left, tilts to the right, or remains horizontal.

> *[Learner 11 points to the option indicating that the seesaw tilts to the right, which is the correct answer.]*
> L 11: I think it is that one.
> PST D: Which of these is more—which one is heavier?
> L 10 *[points to the 15-kg weight]*: This one.
> PST D: This one—are these on the same line?
> L9 and L 10: Yes.
> PST D: Yes, so if this one is heavier, then what will happen? [Scaffolds—dividing the problem into smaller parts].
> L 10: It goes down.
> L 9: It goes there, so that picture.
> PST D: Ok, try it and press "Check answer."
> L 11: Yes, it was.

In the beginning of the excerpt, learner 11 picks the right answer from the three options. To structure the process of choosing the correct option, PST D divides the process into three parts through three questions: (1) Which of the objects is heavier? (2) Are the objects on the same distance from the fulcrum? and (3) What happens when one of the objects is heavier and they are on the same distance from the fulcrum? Simplifying and structuring a complicated process (such as determining which way the seesaw will tilt) by dividing it into smaller components is characteristic for scaffolds (de Jong and Lazonder 2014).

Direct Presentation of Information by the Teachers

The pre-service teachers also directly presented information to the learners during their experimentations. This form of guidance was provided to inform learners of the rule by which the seesaw can be balanced or to inform them of the variables (weight and distance from the fulcrum) that affect the balance. In the following excerpt, a pre-service teacher (PST A) directly presents information to the learners at the conclusion of an assignment in the Game tab. In this assignment, the learners must find the weight of a flower pot which is 1.5 m from the fulcrum using a brick that weighs 10 kg. They have balanced the seesaw by placing the brick 0.75 m from the fulcrum, and they have come to the conclusion that the flower pot weighs 20 kg. The simulation informs them that they have answered incorrectly.

> Learner 1: It wasn't twenty.
> PST A: Yeah, so now you guessed twenty, but because this one (the flower pot) is further away, it has to be in fact lighter than ten kilos. [Direct presentation of information]
> Learner 12: Five.
> PST A: Why do you answer five? [Prompts—prompt for answer]
> L 12: Because I suddenly felt like it.
> Learner 8: Yes, I agree.
> *[The learners enter five kilos. The simulation informs them that their answer is correct.]*
> PST A: It is correct, so it weighs half as much—girls, would you listen to me for just a second?
> Learners: Yes.
> PST A: It weighs half as much as ten kilos because it is twice as far from the fulcrum as the ten kilos is—this is why they are in balance. [Direct presentation of information]

The learners chose the correct ratio for two weights (1:2) in their first answer. By explicitly stating that the object further from the fulcrum must be lighter, PST A informs the learners that the answer must be less than 10 kg. Learner 12 has the right answer but is unable to give a reason for the answer when PST A asks for one. After the correct answer is entered into the simulation, PST A explains that objects weighing half as much must be placed twice as far from the fulcrum. The first direct presentation of information gave the learners qualitative information and the latter quantitative information about how to balance the seesaw. The learners were unable to discover this information on their own, as was apparent from their first incorrect answer and their inability to provide reasons for the correct answer. According to de Jong and Lazonder (2014), it is appropriate to directly provide the learners with information in this situation.

Distribution of Guidance Between the Simulation and the Teachers

Tabak's (2004) three different patterns of distributed guidance are illustrated in this data by examples showing the distribution of the guidance among different guiding elements and actions.

Differentiated Guidance

Identifying learning needs and supporting each of them using the best source and form of guidance available is the principle behind the pattern of differentiated guidance (Tabak 2004). In this study, for example, only the pre-service teachers (and not the simulation) prompted to learners to reflect on their answers to the assignments or on their learning in general. The assignments in the Game tab assign scores based on the number of correct and incorrect answers, but these scores do not take into account for whether the learners used a method or a strategy to solve the assignment or whether they simply guessed the answer. The teachers, on the other hand, prompted the learners to verbally express their strategies for solving the assignments and to give explicit reasoning for their answers. When the learners explicitly state their reasoning for their answers, they devote effort and resources to the scientific content of the answer. The teachers also prompted them to share their ideas with other members of their group, which helped them discover or address disagreements among themselves, prompting them to engage in exploratory discussions (Mercer 1996).

Redundant Guidance

The idea that different learners have different needs for support is the principle behind the pattern of redundant guidance (Tabak 2004). An example of this pattern in this study was when the teachers verbalized and paraphrased the assignments given by the simulation in the Game tab. The excerpt below provides an example of this. In this assignment, the seesaw was shown in a predetermined configuration with supports holding it in place. The learners had to determine what would happen to the seesaw (tilt to the left, tilt to the right, or remain horizontal) when the supports were removed.

> Learner 9: So now…
> Learner 10: This one has to be moved that way.
> L 9: Yeah, this has to be moved this way in order to—
> PST D: That is true, but now—here, you don't have to move these, but if the situation is this: that fifteen kilos is there and the other one is here, which of these options will happen? [Prompts – prompt for action]

Even though the instructions are written on the screen, younger learners in particular may have difficulties understanding what they are expected to do in the assignment. When the learners in this excerpt encountered this type of assignment for the first time, at least two of them did not immediately understand that they could not move the weights on the seesaw and started to discuss where to move them. Some of the learners in the group might have understood the assignment, but at least two did not. So, the teacher verbalized the assignment which transformed the written assignment into a verbal one, going from one mode of expression to another. This redundant guidance provided through different sources and modalities ensured that all members of the group received guidance in the form of a prompt and an assignment (Tabak 2004).

Synergistic Guidance

The idea that different forms of guidance augment one another and work in tandem to guide learner performance is the idea behind the pattern of synergistic guidance (Tabak 2004). An example of synergistic guidance is the interplay between learners' progression through the different levels of assignments in the Game tab and teacher instruction for the learners to either move on to a more difficult level or to stay at the same level. Let us take PST C and his/her group of learners as an example. After completing the first level of assignments in the Game tab, the learners want to move on to level 2 *(*"*Can we go on to level 2 now?*"). PST C agrees to that but adds that they must pay attention to the difficulty of the assignments ("*We can try, but we'll have to see if they [the assignments] are really difficult.*"). The learners go on solving the assignments, but they struggle with some of the assignments because the assignments in level 2 are more complex. PST C acknowledges this ("*This is a really hard one [level].*"). With the teacher's guidance, the learners are able to complete all of the assignments and want to move on to level 3 ("*OK next up is level 3.*"). PST C, however, prevents the learners from moving on ("*Let's just play levels 1 or 2; those previous ones were already really difficult.*"). In this example, the guidance embedded in the simulation (i.e., progression through the different levels) was augmented by the teachers' observations of the learners' skills and knowledge. If guidance was only provided by the simulation, learners could over or underestimate their skills and try to complete levels that are too hard or too easy for them. This would hinder their learning or at least decrease their motivation. The teacher can make use of the progressive difficulty of the levels in the simulation and provide additional guidance that is adapted to the learners' needs. When the guidance provided by the simulation is augmented by dynamic support from the teacher, the guidance is more likely to be effective (Tabak 2004).

Discussion

The results of this study give a glimpse into one case dealing with guidance provided by different sources. The teachers provided more varied guidance than the Balancing Act simulation by providing different forms of guidance through different guiding actions. The guidance provided by the simulation was concentrated around the assignments in the Game tab and the learners' progression through the simulation. These results illustrate how inquiry-based learning is guided by both the teachers and the simulation. Using the same categorization for both providers of guidance made it possible to contrast the forms of guidance provided. It also allowed the patterns of guidance distribution between the different providers to be examined.

The examples from the data for the patterns of distributed guidance by Tabak (2004) all have one characteristic in common: the teacher is the guidance provider that enacts the patterns. This showcases the crucial role that teachers play in guiding inquiry-based learning with simulations. In theory, teachers can adapt their guidance to both the needs of the learners and to the guidance provided by the simulation better than the simulation could and vice versa. We will discuss these two forms of adaptation separately.

Firstly, guidance for inquiry learning with simulations should always be adapted to the needs of the learners, no matter the source of the guidance (de Jong and Lazonder 2014; Smetana and Bell 2012; van de Pol et al. 2010). De Jong and Lazonder emphasize the role of constant monitoring of learners' performance and knowledge in adapting guidance for every learner. Teachers probe the learners' performance and knowledge and adapt their instruction through formative assessment (Black 2009; Buck et al. 2010; Haug and Ødegaard 2015; Ruiz-Primo and Furtak 2007; Ruiz-Primo 2011). This has been argued to be one of the fundamental mechanisms for learning and also for improving learning gains (Black and Wiliam 1998; Jordan and Putz 2004). Especially in informal, formative assessment, teachers consciously discover information about learners' understanding and use this information to alter their immediate instruction (Ruiz-Primo 2011; van de Pol et al. 2010). The teacher can obtain evidence about learner needs and knowledge from multiple sources, including oral evidence (e.g., learners' conversations, questions, and responses), written evidence, graphic evidence, practical evidence (e.g., observing learners' work with a simulation), and non-verbal experience (e.g., body language) (Ruiz-Primo 2011). On the other hand, simulations cannot adapt to learners' needs and knowledge in the same way since they cannot receive as much information about the learners as teachers can. For example, the only information received by the assignments embedded into the Balancing Act simulation is whether the learners complete the assignment in the first, second, or third attempt. Based on this information, the simulation then gives the learner a score or displays the correct answer. More complex learning analytical educational software for science learning exists; such programs can obtain evidence of learner outcomes from different learning products within the software (de Jong et al. 2010). The development of this sort of learning analytical tools that guides learners based on their needs is still under way (de Jong and Lazonder 2014; Ferguson 2012; Olympiou and Zacharias 2013). At this time, the ability of teachers to adapt to learners' needs is far beyond the capacity of any software.

Second, because the guidance provided by teachers can be more adaptive than the guidance provided by a simulation, teacher guidance must adapt to software guidance. Teachers' ability to provide guidance that complements that provided by the simulation ensures that the overall guidance the learners receive is as adaptive as possible. In order for science learning with simulations to be supported as efficiently as possible, all sources of guidance are needed—teachers, simulations, or other learning materials. The guidance should be distributed between different sources in a pattern that amplifies the best features of each source of guidance.

Primarily, the responsibility for creating this beneficial distribution rests with the teachers. They need to be aware of the forms of guidance that the software and other sources can provide and compare those forms of guidance to the learners' needs. In some cases, the software could be the best source of guidance for a particular learning need, and in other cases, teachers might need to augment guidance by software. The patterns of distributed guidance described by Tabak (2004) help illustrate this process. Through pre- and in-service training, teachers could be made more aware of guidance provided by different sources and helped to recognize their own strengths and weaknesses. This could make it possible to provide better overall guidance to learners.

Secondarily, producers of educational software and simulations for science learning are responsible for ensuring productive and optimal interaction between different providers of guidance. In some ways, software can provide better guidance than teachers can: individual learners can interact with the software throughout a lesson and during all inquiry phases, while a teacher can only guide one group of learners at a time or the entire class together. Leaving some guidance to the software enables teachers to focus more on probing learners' needs and providing additional guidance that complements the software guidance. Research is needed to identify which aspects of guidance can be delegated to software and which cannot (van Joolingen et al. 2007). An example of software for inquiry-based science learning with simulations that can be adapted by the teacher is the Go-Lab project (de Jong et al. 2014). This software implements a rich set of tools to provide different forms of guidance throughout the inquiry learning cycle. Teachers can use their own diagnosis of learners' needs at the class level to design inquiry learning spaces using different tools and different forms of guidance to target different phases of the inquiry learning cycle. This enables teachers to combine their ability to gain evidence about learner needs with the software's ability to provide guidance for multiple learners at the same time and can possibly improve the overall quality of guidance in the classroom. Still, the guidance provided by the Go-Lab software has to be pre-programmed by the teacher and cannot be modified on-the-fly. Educational software needs to develop further to enable this sort of flexibility and adaptation.

One source of guidance that could be promoted through software is collaboration with peers. This could involve different types of collaboration scripts that support learning by shaping the way learners interact with each other (Kobbe et al. 2007). For example, guidance provided by software could include prompts for learners to engage in discussions with their peers. Thus, some guidance could be provided by peers in addition to that provided by software and teachers.

Limitations

One limitation of this study is the fact that guidance for inquiry-based learning was only studied in the context of one PhET simulation. The guiding frameworks in which simulations are embedded differ from one simulation to another (Clark et al. 2009); different simulations provide different forms of guidance. This also leads teachers to provide different forms of guidance and to use different patterns for distributing guidance. In order to make generalizations about the guidance provided by simulations and teachers, one would need to collect data from lessons utilizing multiple different simulations. Also, the fact the data was collected from pre-service teachers' and not in-service teachers' lessons has an effect on the guidance provided. In-service teachers with more experience could provide different forms of guidance through different guiding actions. Pre-service teachers' limited content knowledge could have an effect on their teaching, including the guidance they provided (Childs and McNicholl 2007).

Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Funding This study has been partially funded through a grant from the Technology Industries of Finland Centennial Foundation and from the Ellen and Artturi Nyyssönen Foundation.

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IV

THE CONNECTION BETWEEN FORMS OF GUIDANCE FOR INQUIRY-BASED LEARNING AND THE COMMUNICATIVE APPROACHES APPLIED - A CASE STUDY IN THE CONTEXT OF PRE-SERVICE TEACHERS

by

Lehtinen, A., Lehesvuori S., & Viiri, J., accepted for publication in Research in Science Education

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Res Sci Educ
DOI 10.1007/s11165-017-9666-7

The Connection Between Forms of Guidance for Inquiry-Based Learning and the Communicative Approaches Applied—a Case Study in the Context of Pre-service Teachers

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Abstract Recent research has argued that inquiry-based science learning should be guided by providing the learners with support. The research on guidance for inquiry-based learning has concentrated on how providing guidance affects learning through inquiry. How guidance for inquiry-based learning could promote learning about inquiry (e.g. epistemic practices) is in need of exploration. A dialogic approach to classroom communication and pedagogical link-making offers possibilities for learners to acquire these practices. The focus of this paper is to analyse the role of different forms of guidance for inquiry-based learning on building the communicative approach applied in classrooms. The data for the study comes from an inquiry-based physics lesson implemented by a group of five pre-service primary science teachers to a class of sixth graders. The lesson was video recorded and the discussions were transcribed. The data was analysed by applying two existing frameworks—one for the forms of guidance provided and another for the communicative approaches applied. The findings illustrate that providing non-specific forms of guidance, such as prompts, caused the communicative approach to be dialogic. On the other hand, providing the learners with specific forms of guidance, such as explanations, shifted the communication to be more authoritative. These results imply that different forms of guidance provided by pre-service teachers can affect the communicative approach applied in inquiry-based science lessons, which affects the possibilities learners are given to connect their existing ideas to the scientific view. Future research should focus on validating these results by also analysing inservice teachers' lessons.

Keywords Inquiry-based learning · Communicative approach · Classroom communication · Pre-service teachers

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Introduction

This study presents and analyses the role of different forms of guidance (Lazonder and Harmsen 2016) for inquiry-based learning (IBL) have on pedagogical link-making (Scott et al. 2011) by teachers and the communicative approaches (CAs) (Mortimer and Scott 2003) they apply. Episodes from a science lesson implemented by a group of pre-service teachers (PSTs) are analysed to provide examples of these roles.

Inquiry-based learning and related practices have been highlighted as a beneficial way of learning science in policy papers (National Research Council 1996; National Research Council 2000; NGSS Lead States 2013) and meta-analyses (Alfieri et al. 2011; Minner et al. 2010). IBL commonly refers to three main areas: learning to do inquiry (e.g. learning to design and carry out investigations), learning about inquiry (e.g. how scientific knowledge is developed) and learning through inquiry (e.g. conceptual knowledge) (Bybee 2000; Gyllenpalm et al. 2010). Recent research has shown that IBL should be supported by providing guidance for the learners to reach optimal content learning outcomes through inquiry (Alfieri et al. 2011; Furtak et al. 2012; Lazonder and Harmsen 2016). The role of guidance for IBL in supporting learning about inquiry, such as epistemic practices, dialogue and argumentation (Bereiter and Scardamalia 2006; Driver et al. 1994; Osborne 2010), has not been studied to the same extent even though this has been called for (Hmelo-Silver et al. 2007).

The traditional and still dominant (Mercer et al. 2009; Muhonen et al. 2017; Wells and Arauz 2006) authoritative approach to classroom interaction sees the teacher as an authoritative figure who holds the scientific knowledge, which limits the learners' ability to engage in authentic inquiry where ideas are shared and alternative views are considered (Lemke 1990). Through a dialogic approach to classroom interaction, more space is given for learners' own ideas and conceptions, which can then be investigated and either refuted or confirmed through evidence and thus connected with the scientific view (Mortimer and Scott 2003). This connection of existing knowledge and new ideas is central to the constructivist perspective to learning (Larochelle et al. 1998). Teachers should address these connections in their teaching through the process of pedagogical link-making (Scott et al. 2011).

Previous research (Lehesvuori et al. 2011a) provides a holistic model that links different phases of IBL to different communicative approaches but just vaguely describes the role of guidance in enacting these approaches. In this study, we examine a case example about the role that providing different forms of guidance for IBL has on shaping the CAs applied in the classroom. The novelty of this paper lies in combining the multitude of research on supporting inquiry-based learning and processes central to it by providing guidance (de Jong and Lazonder 2014; Lazonder and Harmsen 2016) with the existing research on pedagogical link-making and different CAs (Mortimer and Scott 2003; Scott et al. 2011). The results will provide a new angle to the theory base of both strands of literature.

The goal of the theoretical background presented next is to highlight the theoretical connections between different forms of guidance, different CAs and pedagogical link-making. After this, we draw upon a case example in order to analyse empirically how the forms of guidance provided are connected with pedagogical link-making and different CAs.

Theoretical Background

Inquiry-Based Learning and Guidance

Different definitions for IBL are used in the literature, but they usually include certain phases or features of inquiry (Bell et al. 2010; National Research Council 1996; National Research Council 2000). We conceptualize the different phases of IBL using the inquiry cycle formulated by Pedaste et al. (2015) through a systematic review of the existing literature on IBL. The cycle consists of five phases: stimulating interest (Orientation), stating theory-based questions and/or hypotheses (Conceptualization), planning and carrying out investigations (Investigation), drawing conclusions based on the data (Conclusion) and communicating the findings of a particular inquiry phase or the whole cycle to others and reflecting on one's own actions (Discussion). The discussion phase can be a separate part of the cycle, or it can follow a particular phase of the cycle.

Even though IBL has been advocated as a beneficial method of learning science, as discussed in the *Introduction*, there have also been voices critical of the method. Especially, the cognitive load placed upon the learners by engaging in the processes essential to IBL has been called too heavy, which would render the method ineffective (Kirschner et al. 2006; Mayer 2004). The answer to this critique has been to emphasize the potential of supporting IBL by, for example, the teacher, learning material or simulation (de Jong and Lazonder 2014; Furtak et al. 2012). Meta-analyses have shown that providing support improves the learning outcomes attained (Alfieri et al. 2011; Furtak et al. 2012; Lazonder and Harmsen 2016). This support for learning is often called *guidance* or *scaffolding*. Guidance can be defined as "any form of assistance offered before and/or during the inquiry learning process that aims to simplify, provide a view on, elicit, supplant, or prescribe the scientific reasoning skills involved" (Lazonder and Harmsen 2016, p. 687). Scaffolding, on the other hand, is classically defined as "the process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would be beyond his unassisted efforts" (Wood et al. 1976, p. 90). Both terms are related to instructional support aimed at promoting learning by moving some of the intellectual burden from the learner to a more knowledgeable other (e.g. teacher). While similar features can be found in the literature both about scaffolding (van de Pol et al. 2010) and guidance (de Jong and Lazonder 2014), scaffolding relates more to a process that emphasizes the constant diagnosis of learners' understanding (Puntambekar and Kolodner 2005; van de Pol et al. 2012), whereas guidance relates more to individual guiding actions by teachers (Lehtinen and Viiri 2017) or types of guidance (e.g. tools) that are provided for IBL (de Jong and Lazonder 2014; Lazonder and Harmsen 2016; Zacharia et al.

Table 1 Typology for forms of guidance and their descriptions by Lazonder and Harmsen (2016) (slightly modified from de Jong and Lazonder (2014))

Form of guidance	Description
Process constraints	Reduce the complexity of the learning process by limiting the number of options the learners need to consider
Status overviews	A real-time progress report of the learning process or evolving knowledge which makes the progress apparent
Prompts	Reminders to carry out certain actions or learning processes
Heuristics	Suggestions on how perform a certain action or learning process, such as hints or reminders
Scaffolds	Taking over more demanding parts of a learning process often by structuring the activity
Explanations	Giving out target information or specifying how to perform an action

2015). We use the term guidance in this paper to describe the support for learning provided by the PSTs given its previous use in the literature regarding the inquiry-based teaching of science in general (Lazonder and Harmsen 2016), but we still acknowledge the important contribution to the topic made by the literature on scaffolding.

Different categorizations have been developed to organize guidance for IBL provided to learners (de Jong and Njoo 1992; Quintana et al. 2004; Reid et al. 2003). A recently developed typology by de Jong and Lazonder (2014) and then slightly modified by Lazonder and Harmsen (2016) classifies different forms of guidance according to the specificity of the learning support they offer to the learning processes. The typology is presented in Table 1. This specific typology is used to classify the different forms of guidance provided by the PSTs in this paper, because it has been used in multiple studies regarding guidance for IBL (e.g. (Lazonder and Harmsen 2016; Zacharia et al. 2015)) and especially guidance provided by PSTs for IBL (Lehtinen and Viiri 2017).

The research on guidance for IBL has concentrated on the effects that providing guidance overall (Alfieri et al. 2011; Furtak et al. 2012) or certain forms guidance in particular (Lazonder and Harmsen 2016) have on the content learning outcomes. Lazonder and Harmsen argue that the specificity of the provided guidance can also influence the understanding and appreciation of different epistemic practices related to inquiry. Hmelo-Silver et al. 2007 also point out that learning *softer skills* such as epistemic practices related to science or learning how to collaborate (Bereiter and Scardamalia 2006) need to be considered in addition to science content learning outcomes when designing guidance for IBL.

Communicative Approaches Applied in the Classroom and Pedagogical Link-Making

Mortimer and Scott (2003) have developed a framework that describes classroom discourse with two dimensions: interactive/non-interactive talk (I/NI) and the authoritative/dialogic (A/D) approach. Interactive talk allows the learners to participate, whereas non-interactive talk is a lecture in which the learners are not expected to participate. The dialogic approach takes into account learners' different and possibly diverging ideas, whereas the authoritative approach focuses on one particular idea or view—usually the prevailing scientific view—controlled by the teacher. These two dimensions can be combined to form four different communicative approaches (CAs) that teachers can apply. The four CAs and their descriptions are listed in Table 2.

Table 2 The communicative approaches and their descriptions by Mortimer and Scott (2003)

Communicative approach	Description
A/I	A question-answer routine where learners' responses are evaluated by the teacher and ideas diverging from the scientific point of view are rejected. The focus is on the scientific view.
D/I	Learners' ideas are elicited and then explored without evaluation. The teacher is not trying to achieve a specific point of view but instead works with the learners' views.
A/NI	The teacher lectures and presents the scientific content. The focus is on a specific point of view.
D/NI	The teacher takes into account contrasting points of view, such as learners' own ideas. Even though the teacher is lecturing, different points of view are being taken into account.

Even though CAs consist of multiple teacher-learner exchanges, some features regarding a single turn of conversation have been identified as indicators of a certain CA (Lehesvuori et al. 2017). Indicators of a dialogic approach include teachers' open questions (Alexander 2006, p. 41; Chin 2007) that elicit explanations or predictions from the learners without the teacher knowing the answer beforehand. On the other hand, closed questions rarely lead to dialogic interaction, because they aim for pre-defined answers (Chin 2007). Teacher feedback is another indicator of different CAs. Evaluative feedback can be an indicator of an authoritative approach, because it presents the teacher as the more knowledgeable one in the discussion. Reacting to learners' responses with another question or initiation (thus forming an IRFRF pattern (Mortimer and Scott 2003)) supports the learners in elaborating and making their ideas explicit (Scott et al. 2006). This pattern indicates a more dialogic approach to classroom communication.

Dialogic and authoritative CAs have different possibilities for promoting practices related to IBL. Conducting investigations based on learners' preconceptions about the phenomenon under study and then argued for or against them using evidence from the investigations is central for IBL (Rönnebeck et al. 2016). Thus, engaging in argumentation and working with conflicting views can be seen as part of the epistemic practices related to IBL (Driver et al. 1994; Furtak et al. 2012; Osborne 2010; Rönnebeck et al. 2016). Science classrooms' typical communication pattern, the so-called IRF triadic dialogue (Lemke 1990), which consists of the teacher's *Initiation* of talk (e.g. a question), the learner's *Response* and the teacher's *Feedback* (Sinclair and Coulthard 1975), does not promote learning these practices. Seeing the teacher as the authoritative figure who gives feedback on the learners' responses based on the prevailing scientific view limits the learners' ability to engage in authentic inquiry, where ideas are shared and alternative views are considered (Lemke 1990; Sadeh and Zion 2009). Eliciting learners' own ideas and conceptions and contrasting them could help the learners form an authentic view of scientific inquiry, where preference is given to claims which are backed up by evidence and that are shared with peers (Driver et al. 2000; Sadler 2006). Scott et al. (2011) use the term "pedagogical link-making" to describe the practices of teachers and learners in making connections between ideas through interactions in the classroom. They identify three different forms of pedagogical link-making:

1. Supporting knowledge building
2. Promoting continuity
3. Encouraging emotional engagement

Each of these forms can contain different types of approaches; for example, knowledge building can be supported by making links between every day (i.e. learners' existing ideas) and scientific ways of explaining or by making links between different scientific concepts. These links can take place during a time scale of years (making links to learning or teaching in different parts of curricula) to minutes (making links referring to different parts of the same lesson). An example of link-making taking place within a lesson is the "opening up" and "closing down" of discussions (Scott and Ametller 2007). Discussions (that can last from a few minutes to the whole lesson) can be "opened up" with a dialogic approach, which enables the learners' existing views to be collected and worked with. Even though applying dialogic approaches to communication in the classroom enables the learners to practise skills related to authentic inquiry, there is also a place for authoritative approaches. These can be necessary when the gap between the learners' existing ideas and the prevailing scientific view is too large to be addressed through the dialogic aspect alone (Lehesvuori et al. 2011a). Thus, discussions that were "opened up" through dialogic approach should be "closed down" when necessary using an authoritative approach to classroom communication. By eliciting the learners' existing ideas and views in the "opening up" stage, the learners are able to make links between them and the scientific view presented in the "closing down" phase. This sort of cumulative structure (Lehesvuori et al. 2013) of discussion enables meaningful links to be made between learners' existing understanding and the prevailing scientific view, and thus, information is built on top of learners' previous experiences and knowledge (Alexander 2006, p. 28; Mercer 2008; Scott and Ametller 2007; Scott et al. 2011). In general, meaningful science teaching should contain both authoritative and dialogic approaches (Scott and Ametller 2007), but we do not argue for always following dialogic discussions with authoritative talk. The need for authoritative approach for classroom communication is dependent on the situation and the judgement of the teacher.

Theoretical Connection Between Forms of Guidance and Communicative Approaches

Based on existing conceptualizations of CAs and forms of guidance for IBL, we argue that the authoritative–dialogic dimension of classroom communication by Mortimer and Scott (2003) bears a resemblance to the continuum of specific–non-specific guidance by de Jong and Lazonder (2014) and Lazonder and Harmsen (2016). Providing more non-specific forms of guidance, such as process constraints or prompts, gives more space to the learners' own ideas, which can then be explored through a dialogic approach. This can happen when the whole class discussion is *opened up* (Scott and Ametller 2007) and the learners' ideas are explored. On the other hand, when an authoritative approach is applied to classroom communication, the teacher can be seen as taking the side of the prevailing scientific view. The learners can be led toward this view by providing more specific forms of guidance, such as scaffolds or explanations. This can happen in the *closing down* phase of discussion (Scott and Ametller 2007) where the teacher links the ideas that were previously elicited from the learners with the prevailing scientific view. This would be an example of two forms of pedagogical link-making, both supporting knowledge building and promoting continuity (Scott et al. 2011). Scott and Ametller describe the structure of *opening up* and *closing down* discussion as one that supports meaningful science learning.

Aim of the Case Study

As the theoretical basis for studying the role of different forms of guidance in building different CAs has been outlined in the previous sections, we will move on to analysing two excerpts from an example lesson. Through analysing the guidance provided in these two excerpts, we investigate analytically the previously theoretically argued connection. The analysed excerpts showcase the opening up and closing down of classroom discussions (Scott and Ametller 2007) and the pedagogical link-making (Scott et al. 2011) that occurs between these two episodes. The role of different forms of guidance provided by teachers and the effect they may have on the CAs applied by in the classroom has not been studied, even though there is a call for research on the effect providing different forms of guidance on science teaching processes (Hmelo-Silver et al. 2007; Lazonder and Harmsen 2016). This paper complements the existing literature on guidance for IBL by also analysing the role different forms of guidance have on the CAs applied in the classroom discourse through a case example.

Our research question is:

What is the role of providing different forms of guidance for inquiry-based learning on building the communicative approach applied by the pre-service teachers in the lesson under study?

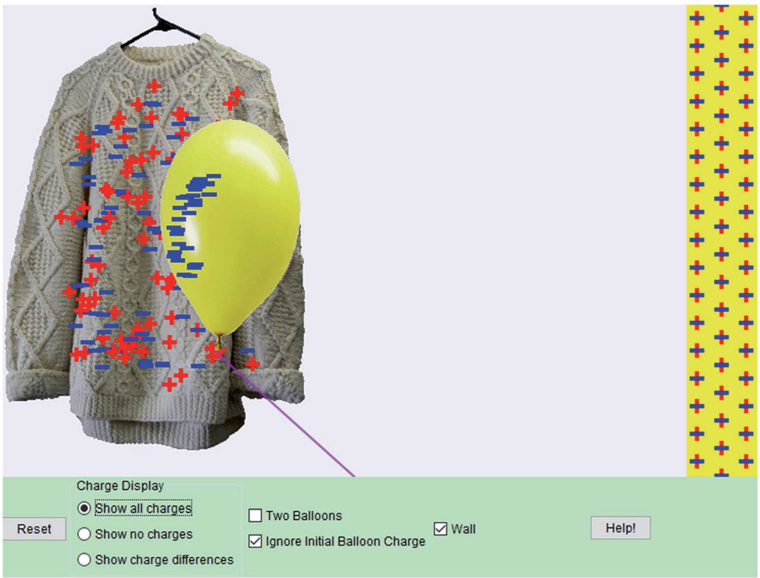
Context of the Study

The context of the case example is primary PSTs' teaching of physics at the primary level. PSTs' inquiry-based teaching might differ from that of in-service teachers due to, for example, their limited content knowledge (Childs and McNicholl 2007) or their limited understanding of inquiry-based teaching (Demir and Abell 2010; Seung et al. 2014; Yoon et al. 2012). PSTs' perceptions of teaching are based mainly on their own experiences in school as learners (Abell 2000). These experiences are based on classroom interaction mostly based on lecturing and closed questions with evaluative feedback (IRF pattern) (Mercer et al. 2009). Through pre-service teacher training, secondary PSTs have been able to implement science lessons that contain both dialogic and authoritative approaches (Lehesvuori et al. 2011b), and primary PSTs have improved their conceptions toward more dialogic inquiry-based teaching (Lehesvuori et al. 2011a). Regarding guidance by PSTs for IBL, Yoon et al. (2012) report that Korean PSTs describe having difficulties with balancing between guiding the learners in their IBL activities and giving them space to work on their own. Lehtinen et al (2016a) report the same issue in a Finnish context regarding IBL where simulations are used to conduct the investigations.

The data for the case example were collected as a part of an intervention for primary PSTs ($n = 40$) (see Lehtinen et al. 2016b for extensive details on the whole study cohort) aimed at promoting the use of simulations for IBL. Simulations mimic the behaviour of a real system and allow learners to observe the effect of interacting with this system (de Jong and Lazonder 2014). They are very well suited to be used as a part of IBL because they allow the learners to freely investigate different hypotheses or research questions and thus come to conclusions. They also allow for the visualization of otherwise unobservable features, such as electric charges moving from one object to the other. Literature reviews have concluded that investigations performed using simulations enhance students' conceptual understanding and motivation when compared with lecturing or laboratory activities (Rutten et al. 2015; Smetana and Bell 2012).

Participation in the intervention and the study was voluntary for the PSTs, and written consent for the study was collected. The intervention was integrated into the PSTs' science methods course and was conducted in a period of two months, with weekly 90-minute meetings and independent homework. The main part of the intervention was the planning and implementing of an inquiry-based science lesson where simulations had to be used to conduct at least part of the investigations. This planning and implementation was done in groups of five PSTs each. The first third of the intervention was used to introduce the PSTs to the basic structure of IBL in science and to the PhET (Physics Education Technology) simulation database (University of Colorado Boulder 2017). The last two thirds were spent on the planning and implementation of the lesson. To ensure that the PSTs obtain experience in teaching inquiry-based science with simulations, each of the groups were instructed to use a certain PhET simulation as a part of their lessons. The planning process was supported by feedback from the two teacher educators in charge of the intervention and by using peer feedback. This was done to surpass the most common difficulties in IBL, such as how to get the learners to generate hypotheses or draw conclusions (de Jong and van Joolingen 1998; García-Carmona et al. 2016). The lessons were implemented in primary school science lessons from third to sixth grade.

The case example is one of the eight lessons implemented as part of the intervention. This lesson was chosen for this case study because the five PSTs implementing that particular lesson applied the dialogic approach more than PSTs from any other lesson. The lesson also featured all the five phases of IBL as defined by Pedaste et al. (2015). The five PSTs who planned and implemented this lesson were five females ($M_{\text{age}} = 26$, $\text{SD}_{\text{age}} = 4$) of which four had under six months of teaching experience and one had between one and a half and two years of teaching experience. None of them had used simulations in teaching or learning science before the intervention. The topic of their lesson was "Static Electricity", and the simulation used to conduct part of the investigations was the "Balloons and Static Electricity" simulation from the PhET database (University of Colorado Boulder 2017). Figure 1 shows the simulation. The lesson topic and the simulation used were decided in cooperation with the participating class's teacher to fit their curriculum at the time of the data collection. The topic of static electricity is familiar to most primary-aged learners from their everyday life, which enables them to possibly have their own everyday ideas about the phenomenon. In addition to the simulation, the learners



Charge Display
● Show all charges
○ Show no charges
○ Show charge differences
☐ Two Balloons
☑ Ignore Initial Balloon Charge
☑ Wall

Fig. 1 The "Balloons and Static Electricity"—simulation used in the lesson under study also used different hands-on equipment such as balloons, transparencies, combs and scraps of paper to conduct part of the investigations. Previous research has indicated that combining the use of simulations and hands-on material benefits primary-aged learners more than using just a simulation to conduct the investigations (Jaakkola et al. 2011).

The whole class phases (other than the Investigation phase) were orchestrated by one or two PSTs with the others observing. During the Investigation phase, each PST guided one small group of learners in their experiments. The learners first investigated static electricity using the "Balloons and Static Electricity" simulation where they could interact with a balloon and sweater and experiment with them. The simulation visualized how the negative charges from the sweater are transferred to the surface of the balloon, causing the sweater to become positively and the balloon negatively charged. After using the simulation, each group of learners could investigate same phenomena using different hands-on material such as combs or transparencies. Through these hands-on investigations, the learners could connect the observations made from using the simulation to the real-world scenario. The simulation was available for use also during the hands-on investigations.

The lesson under study was implemented in a class of 15 sixth graders aged 11 to 12 as part of their science curriculum. The course of the lesson divided into episodes and the phases of inquiry by Pedaste et al. (2015) is described in Table 3.

Methods

The data used for this study was collected primarily by two video cameras, which recorded the lesson from the front and the back of the classroom. These two cameras recorded both the audio and the video of the whole class teaching episodes in front of the classroom and smaller groups' investigations that were conducted around five different table groups in the classroom.

Table 3 The episodes and their topics divided into the phases of inquiry by Pedaste et al. (2015)

Phase of inquiry	Episode/min	Topic
Orientation	E1 / 0–2	Teacher-led demonstration of static electricity
	E2 / 2–3	Learner demonstrates the phenomenon in front of the class
Conceptualization	E3 / 3–5	Probing learners' ideas regarding the phenomenon, which are then written on the blackboard
	E4 / 5–6	Learners' come up with ideas in small groups
	E5 / 6–8	More probing for learners' ideas regarding the phenomenon, which are also written on the blackboard
	E6 / 8–9	Instructions for investigations
Investigation	E7 / 9–27	Conducting the investigations
Discussion	E8 / 27–28	Instructions to end the investigation
	E9 / 28–30	Collecting the first group's findings from their investigations
	E10 / 30–31	Collecting the second group's findings from their investigations
	E11 / 31–32	Collecting the third group's findings from their investigations
	E12 / 32–33	Collecting the fourth group's findings from their investigations
	E13 / 33–34	Collecting the fifth group's findings from their investigations
Conclusion	E14 / 34–36	Coming back to the first idea on the blackboard
	E15 / 36–37	Coming back to the second idea on the blackboard
	E16 / 37–38	Coming back to the third idea on the blackboard
	E17 / 38–39	Coming back to the fourth idea on the blackboard

The investigations with the simulations and the hands-on material were both conducted around the same desks. Even though the focus of this case study is on the whole class teaching episodes, additional audio data was collected using screen capture programs running on the laptops that ran the simulations. This audio was used to analyse the learners' and teachers' actions during the Investigation phase of IBL. All the video and audio data was transcribed, and both the transcriptions and the video and audio data were used in the analysis. Overall, the data used in the analysis amounted to 140 minutes of video and audio.

The analysis of the video data began with defining the phases of IBL present in the lesson. This was done using the descriptions for the phases of IBL from Pedaste et al. (2015) and comparing the teaching-learning processes in the lesson to those descriptions. The lesson was divided into five phases of IBL based on this analysis. After this, the analysis was conducted as two parallel and separate processes: one dealing with the analysis of the guidance provided by the PSTs for IBL in the lesson and the other dealing with the analysis of the CAs applied by the PSTs in different episodes during the lesson.

The basis for the analysis of the forms of guidance was the descriptions of the forms of guidance by de Jong and Lazonder (2014) and Lazonder and Harmsen (2016), examples from previous research on different forms of guidance provided by software by Zacharia et al. (2015) and previous research on how these forms manifest themselves as *guiding actions* that the teachers verbally provide (Lehtinen and Viiri 2017). A guiding action was defined as a teacher's verbal action that fits one of the descriptions for forms of guidance by Lazonder and Harmsen. These guiding actions were single teacher utterances (e.g. Prompt: "Why do you want to reject the hypothesis?") apart from the guiding actions that were provided as scaffolds. According to the definition of de Jong and Lazonder, scaffolds support the dynamics of the activity, often by providing learners with the components of the process, which provides structure. Teachers provide similar support by, for example, asking multiple closed questions in a row when the learners are presenting the results of their investigations (Lehtinen and Viiri 2017). The questions provide structure for the complex problem of reporting one's results. Thus, scaffolds are often longer than single utterances and consist of few teacher Initiation–learner Response turns. The coding for different forms of guidance could have been continued by forming data-based categories for guiding actions e.g. prompts (Lehtinen and Viiri 2017). This was not done in this paper, because the used coding only served as a basis for the further analysis of the roles the different forms of guidance have on building the CA. Instead, during the further analysis detailed in the Findings section, the role of each guiding action was analysed individually.

The analysis for the CAs applied by the PSTs started with defining the units of analysis—episodes. We define an episode change as happening whenever there was a change in topic, a contrast in behaviour or a transition to the next type of conversation or activity (Jordan and Henderson 1995). Multiple episodes can be contained within the same phase of inquiry. For example, moving from a teacher-led demonstration to a demonstration where a volunteer learner is called in front of the class to demonstrate the same phenomenon is seen as a transition from one episode to another even though they both are a part of the Orientation phase of inquiry. The episodes and their topics are presented in Table 3.

After this, the dominant CA was defined for each episode. When defining the dominant CA, attention was paid to the fact that authoritative episodes could contain dialogic passages or attempts that still do not transform the sequence into a dialogic one or vice versa. Definitions by Mortimer and Scott (2003) were used in defining the dominant CAs. To illustrate the overall communicative structure of the lesson during the whole-class teaching sequences, a communication graph was constructed (Fig. 2). Our analysis focuses only on the whole class

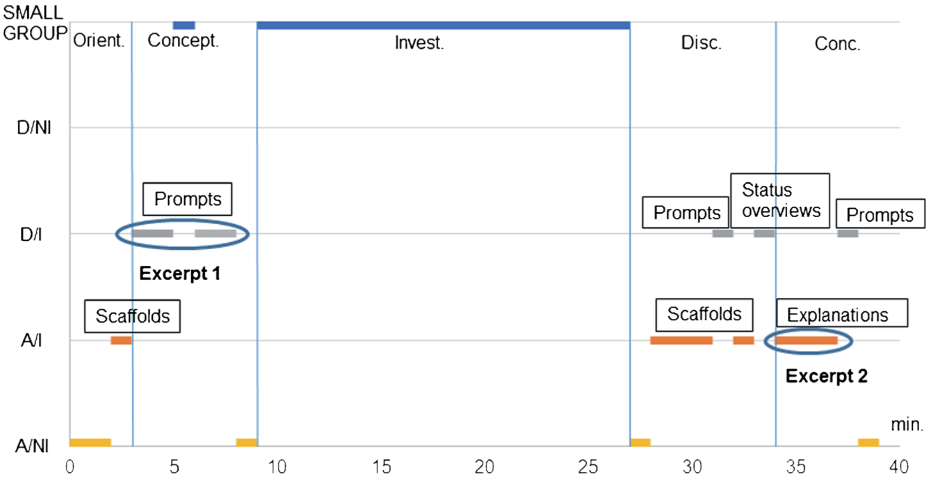


Fig. 2 The phases of inquiry, communicative approaches applied in the different episodes, dominant forms of guidance in the episodes and the analysed excerpts

teaching sessions (so not on the Investigation phase). Similar communication graphs have been used previously to visualize different CAs applied in science lessons (Lehesvuori et al. 2013). The graph showcases the dominant CAs for each episode and their temporal position in the lesson. There were no guiding actions in the episodes that were categorized as authoritative and non-interactive. We define the dominant form of guidance by analysing the role of each guiding action (which each has a certain form) in forming the CA of each particular episode. The dominant form of guidance plays the largest role in forming the CA. This analysis is gone through in more detail in the Findings section of this paper through the excerpts from the data.

Trustworthiness

By providing a thick description (Lincoln and Guba 1985) of the data and analysis procedure we aim to provide an account on the transferability of the findings. We also mostly “stay close to the particulars” (Simons 2015) within the presented case lesson. The crucial temporal aspect of teaching (Lemke 1990; Scott et al. 2011) is highlighted by concentrating on the analysis of one case lesson. Reliability scores were not calculated for the codings due to a) the small amount of data, b) the case nature of this study, c) the fact that researcher triangulation was conducted throughout the research process (Miles and Hubermann 1994) – the first author carried out the primary video analysis, and the findings were evaluated and discussed between the authors until consensus was achieved – and d) the preliminary interpretations were presented and discussed with experts of classroom communication analysis. In previous studies with similar data, good reliability scores have been achieved for the analysis of PSTs’ guiding actions (Lehtinen and Viiri 2017) and for the analysis of PSTs’ CAs (Lehesvuori et al. 2011b).

Findings

Figure 2 illustrates the phases of inquiry, the communicative approaches applied and the dominant forms of guidance in these episodes.

As shown in Fig. 2, non-specific types of guidance (prompts and status overviews) were the dominant forms of guidance in the episodes, where the communication was dialogic and interactive. On the other hand, in the episodes where the communication was classified as authoritative and interactive, more specific forms of guidance (scaffolds and explanations) were dominant.

The two analysed excerpts come from the opening up and closing down parts of the lessons. The first excerpt is from the Conceptualization phase and the second from the Conclusion phase of inquiry. PSTs' Initiations, learners' Responses and PSTs' Feedback are marked on to the excerpts with numbers in subscript to represent which learner is responding. The guiding actions provided by the PSTs are also listed and marked by bold type.

Excerpt 1—Opening Up the Lesson Through Providing Prompts

The following excerpt comes from the Conceptualization phase of the lesson. In consists of two whole-class teaching episodes (E3 and E5 in Table 3) separated by a small group discussion. Before the excerpt, the PSTs have demonstrated static electricity in the Orientation phase by rubbing a balloon with a woollen sweater and watching it stick to a wall and push other balloons. In the excerpt, PSTs A, B, C and D orchestrate a whole group discussion about the learners' ideas regarding the demonstration.

1	*PST A:*	*My hair stood up—didn't it—and then the balloon got stuck to the wall—the one a bit better and the other one not so well—and then there was some small movement when Victoria moved the balloon—**what really happened there**? Oliver tell us.*	I	Prompt
2	*Oliver:*	*Static electricity.*	R_1	
3	*PST A:*	*Good—we will now collect together your ideas and observations about this phenomenon—static electricity—**can you, Oliver, tell a bit more accurately what is static electricity—have you ever done that with a balloon?***	F/I	2 X Prompt
4	*Oliver:*	*Well yeah... Static electricity is that thing when something becomes electric when you rub it if I remember correctly.*	R_1	
5	*PST B:*	*OK so we'll write that something becomes electric when you rub it... **Does anyone else have some ideas**?*	F/I	Prompt
		(PST D writes “A thing turns electric when it's being rubbed” on the blackboard)		
6	*PST C:*	*Some sort of explanations of why this happens.*		
7	*PST A:*	*Yes we are not even looking yet for the final answer, because there are a lot of ways to look at these physical phenomena.*		
8	*PST B:*	*So you don't have to think if this is right or wrong but just, well, what you think—**why did the balloons do what they just did**?*	I	Prompt
9	*PST A:*	*Do you have any ideas Mary or Jane or Julia... **have you tried that sometimes**?*	I	Prompt
		(Mary, Jane and Julia nod.)	R_2	
10	*PST A:*	*OK, so you know the phenomena.*	F	
11	*PST B:*	*What if we'll give you a minute to discuss in your own groups, and then we'll collect your thoughts if you have something new—so think in your own group for a while about **why do these balloons stick to the wall when they were rubbed to the scarf and why did it move on the desk**—you can talk for about a minute and we can walk around.*	I	Prompt
12	*PST A:*	*And those answers can elaborate on what Oliver said or they can be completely different thoughts.*	I	

The episode begins with PST A prompting the learners about their ideas regarding the demonstration with the balloons (turn 1). Oliver brings up the term static electricity in his answer (turn 2), and PST A affirms the term (turn 3). PST A continues to prompt Oliver about static electricity (turn 3), and his answer is written on the blackboard. The discussion turns again to the whole class with PST A's prompt (turn 5). As no one answers, PSTs A and B explicitly state that there is no one correct answer (turn 7) and that all ideas are welcome in the discussion (turn 8). When the learners still do not offer their ideas for discussion even when prompted (turn 9), PST B instructs the learners to discuss their ideas with their peers (turn 11). During the small group work, two ideas are written on the blackboard based on the learners' ideas: "Electricity is magnetic → electromagnetism" and "The balloons repel one another". After this, PST B continues with the whole class teaching.

13	*PST B:*	*OK so now you have had a minute to discuss and part of your ideas have already been written on the blackboard, but now* ***could you tell what your group came up with?*** (gestures to one of the groups)	I	Prompt
14	*Larry:*	*Yes, at least that electricity is sort of a magnet.*	R$_3$	
15	*PST B:*	*Electricity is sort of a magnet, OK…* ***So is it a bit like this one we have already*** **"Electricity is magnetic"** ***?***	F/I	Heuristic
		(Larry nods)	R$_3$	
16	*PST B:*	*OK* ***did you girls have something, Julia or Jane or Mary?***	F/I	Prompt
17	*Julia:*	*If you rub the balloons they start to repel one another and they can also pull, for example, hair to it.*	R$_2$	
18	*PST A:*	*Yeah, yeah.*	F	
		(PST C adds "Pull things toward them" to the blackboard to complement the statement "The balloons repel one another".)		
19	*PST B:*	***You came up with really good ideas in your groups.***	F	Status overview

The second episode begins with PST B prompting two of the groups for their ideas (turns 13 and 16) and pointing out a similarity between Larry's idea and a statement already on the blackboard (turn 15). The episode ends with PST B giving positive feedback to the learners on their actions (turn 19).

When analysing the roles different forms of guidance play in building the CA throughout these two episodes, we must investigate what forms of guidance are provided and which are not. Looking first at what forms of guidance are provided, multiple prompts are used to elicit learners' conceptions and existing ideas regarding static electricity. The prompts are open questions that are used to collect the learners' ideas about the demonstration from the Orientation phase, which served as a primer for the prompts. After the first initial prompts in the first episode, the learners are reluctant to share their ideas with the whole class. After the prompts in turns 5 and 8 attempt to invite more learners to share their ideas, the prompt in turn 11 instructs the learners to discuss the ideas in groups with their peers. The talk between peers when compared with the teacher-learner talk can promote engagement in discussions and argumentation and increase the ownership of information (Barnes and Todd 1977). Through peer discussions, more ideas are brought forward by listing them on the blackboard. This ensures that they remain a part of the discussion for the duration of the whole lesson. In turn 15, PST B recognizes that Larry's idea resembles an idea that is already on the blackboard. Through a heuristic, she guides Larry to see the connection. At the end of the episode, PST B provides the learners with a status overview, which gives the learners a real-time report on their work thus far.

When analysing what forms of guidance are missing from these episodes, the main attention can be given to the lack of explanations by the PSTs. Even though the learners' ideas are not in unison with the scientific view (e.g. Larry in turn 14), the PSTs do not give out this information. Instead, they just acknowledge the learners' ideas (e.g. in turns 5 and 16) without evaluation. This reduces the teachers' level of authority and gives more space to the learners' own conceptions (Osborne 2010).

In these two episodes, the PSTs succeed in opening up (Scott and Ametller 2007) the discussion by giving the learners opportunities to express their ideas, which enables them to be worked with throughout the lesson. This is achieved through providing the learners with multiple prompts as a form of guidance. Overall, the dominant CA in the episodes is interactive and dialogic. Arguments for this interpretation can be expressed through the following points:

- The PSTs use multiple prompts to elicit learners' ideas, which also allows the learners to participate.
- PSTs' responses to these ideas are not evaluative, and explanations are not provided to close the gap between the ideas and the scientific view. Instead, in turns 3 and 15, the response serves as a new question, probing the learners for more elaboration and forming an IRFRF pattern (Mortimer and Scott 2003).
- The ideas are written on a blackboard, enabling the PSTs to work with these ideas throughout the lesson and bringing them forth as valuable contributions.
- Peer discussions are encouraged. Prompting the learners to talk with one another increases the reciprocity of teaching and encourages the sharing of ideas and consideration of alternative viewpoints (Alexander 2006, p. 28).

Excerpt 2—Closing Down the Lesson Through Providing Explanations and Making Links

The second excerpt comes from the Conclusion phase of the lesson. It consists of two whole-class teaching episodes (E14 and E15 in Table 3). After investigating with the simulation and the hands-on materials in small groups in the Investigation phase and going through each group's observations in the Discussion phase, the PSTs turn the learners' attention back to the ideas listed on the blackboard in the Conceptualization phase (previous excerpt). PSTs A, B, C and E orchestrate a whole-class discussion.

20	*PST A:*	*At the bottom of the blackboard we had:* “The balloons repel one another and pull things toward them”.		
21	*PST B:*	*What do you say—**can we dismiss or accept this claim?***	I	Prompt
22	*Paul:*	*Dismiss.*	R_1	
23	*PST B:*	***Why do you want to dismiss it?***	I	Prompt
24	*Paul:*	*Well because they repel one another but it has to do with the electric charge—*	R_1	
25	*Oliver:*	*And besides—*	R_2	
26	*Paul:*	*It's not the balloons that repel one another—it's the electric charge that the balloons and the other object had that repel each other.*	R_1	
27	*Oliver:*	*And they don't attract.*	R_2	
28	*PST B:*	*Yes that was—*	F	
29	*PST C:*	***Very well said.***	F	Status overview
30	*PST B:*	*Yes.*	F	

31	*PST A:*	***So the balloon in itself—any kind of balloon—it doesn't pull everything to itself—it's not like the Earth's gravity, isn't that so***? *Good point—or, in a way—* ***you found the heart of the matter*** *in your observations, yeah…*	F	Explanation Status overview

The first episode begins with PSTs A and B prompting the learners about the first of the learner-generated ideas on the blackboard (turns 20 and 21). After a PST B's prompt for reasoning (turn 23) for Paul's answer for rejecting the idea (turn 22), Oliver and Paul give their reasoning based on their investigations with the simulation, which visualized the electric charges on the balloons (turns 24–27). PST C provides a status overview (turn 29), which provides information to the learners about the good quality of Paul's and Oliver's answers. PST A closes the discussion by providing an explanation between the differences between the pull caused by Earth's gravity and the pull that the learners observed in the Orientation phase of the lesson between the rubbed balloon and the wall. After this, the next episode starts with the next learner-generated idea on the blackboard.

32	*PST A:*	*… how is it with magnetism—* ***in the beginning there was a lot of talk about electromagnetism and magnetism—what do you think about that?***	I	Prompt
33	*PST B:*	*Oliver.*	I	
34	*Oliver:*	*Well, the so-called magnetism is caused by the electric charge—it is not really magnetic, the charge causes it*	R_2	
35	*PST A:*	***You used the words "so-called", so magnetism is maybe something else.***	F	Heuristic
36	*PST B:*	*Yes.*	F	
37	*PST A:*	***Magnetism is what, for example, birds use to orient themselves—they use magnetic fields*** *—isn't that so?—* ***there were some observations that there was something similar as with magnets—they repel each other. I played with train tracks when I was younger, and you know that the train cars stick to each other one way and the other way they don't, and that's a magnetic phenomenon, but now, like Oliver said, this phenomenon was about electricity.***	F	Explanation
38	*PST B:*	*Yes, so we could put parentheses around it or do we dismiss it all together?… Let's dismiss it.*	F	
39	*PST A:*	*What do you say, Oliver—I already drew one line—* ***do we dismiss it?***	I	Prompt
40	*Oliver:*	*In principle, we dismiss it, because it is not magnetic.*	R_2	
41	*PST E:*	***It's a completely different phenomenon.***	F	Explanation
42	*PST A:*	***So a similar thing but still different.***	F	Explanation

The second episode also begins with PST A prompting the learners about an idea on the blackboard (turn 32). Oliver's answer (turn 34) distinguishes between magnetism and electric charge. PST A seizes upon Oliver's words and provides a heuristic through a hint (turn 35) that, in fact, magnetism is something different from the phenomenon under study. After this, PST A gives examples about phenomena relating to magnetism—birds' orienting themselves with Earth's magnetic fields and toy trains sticking together—and thus gives an explanation (turn 37) about the differences between magnetism and electric charges. After PST A's prompt (turn 39) to possibly dismiss the idea, PSTs E and A provide final explanations (turns 41 and 42) to differentiate between magnetism and electric charges.

In these two episodes, the explanations that PSTs A and E provide play a dominant role in building the dominant CAs. The explanations give additional content information relating to the leaner-generated idea under discussion in both episodes. By providing the explanations after prompting the learners for their ideas, the PSTs can be seen as holding the scientific view and presenting it to the learners through the explanations. Even though Paul's and Oliver's answers are not in conflict with the scientific view, by giving the explanations, the PSTs ensure that all learners are able to make the connection between the ideas collected in the Conceptualization phase and the scientific view (Scott and Ametller 2007). In addition, the heuristic guiding action in turn 35 where PST A takes an affirmative position to Oliver's preceding answer has an effect on the CA. By reasserting Oliver's response to the prompt and hinting at the difference between magnetism and electric charges, PST A evaluates Oliver's answer and takes an authoritative position.

Two types of pedagogical link-making can be discerned from these episodes. The first type is evident in both episodes when PSTs A and B form a micro-scale link to the events of the first excerpt by referring to the learners' pre-existing ideas written onto the blackboard (turns 20–21 and 32). This link promotes continuity throughout the lesson by referring explicitly to the learners' ideas elicited during the Conceptualization phase of inquiry and develops the scientific story (Scott et al. 2011). The guidance in the form of prompts (turns 21 and 32) serves to close this pedagogical link. This sort of cumulative structure where new knowledge is built on top of previous knowledge reflects the epistemic practices of inquiry (Furtak et al. 2012; Osborne 2010) and learning about inquiry (Bybee 2000; Gyllenpalm et al. 2010). The second type is evident when the PST A links the scientific way of explaining with the everyday way of explaining and real-world phenomena (turns 31 and 37) by differentiating between them. This happens through her providing guidance in the form of explanations on those turns. These explanations promote knowledge construction and are aimed at ensuring that the learners are able to differentiate between the pull of Earth's gravity and the pull of an electrically charged balloon (turn 32) or magnetic and electric phenomena (turn 37).

Similar to the first excerpt, multiple prompts (e.g. turns 21 and 32) are used to elicit learners' conceptions on the ideas collected in the Conceptualization phase. These prompts form a pedagogical link that promotes continuity throughout the lesson and enables the learners to connect their pre-existing view with the information gained from the Investigation phase of inquiry. The difference here compared to the first excerpt is that in these two episodes the learners' responses to these prompts are systematically followed by heuristics and explanations that serve as authoritative teacher turns. These specific forms of guidance form a pedagogical link that promotes knowledge construction.

In these two episodes, the PSTs close down the discussion that was opened up by collecting the learners' ideas in the Conceptualization phase that were then investigated in the Investigation phase. Even though Oliver and Paul were able to move from their peers' initial ideas of magnetism and electric charge being connected with each other to the scientific view, all learners might not have succeeded in the same. By closing down the discussion with an authoritative approach and a pedagogical link, the PSTs ensure that the scientific view relating to electric charge is clarified for all learners. Overall, the dominant CA applied in these two episodes is authoritative and interactive. Arguments for this interpretation can be expressed through the following points:

- The PSTs' prompts promote interaction between the learners and PSTs.
- Learner responses to these prompts are followed by specific forms of guidance (heuristics and explanations). This guidance does not build on the learners' responses but instead showcases the scientific view in regard to the ideas collected at the beginning of the lesson.
- There are some cases of the IRF pattern (e.g. turns 39–42) (Sinclair and Coulthard 1975) in the discourse, which is one possible signal of an authoritative CA (Scott et al. 2006).

Discussion

The findings of this case example showcase how providing guidance for IBL with differing specificity had an effect on the CAs that the PSTs applied in their teaching. Providing series of prompts (low level of specificity) in the Conceptualization phase of the lesson enabled the PSTs to collect learners' ideas regarding the demonstration from the Orientation phase. Learners' ideas were not evaluated with explanations or heuristics (high level of specificity), but instead the PSTs worked with these different points of view stemming from the learners' ideas (Scott et al. 2006). Prompting for ideas opened up the lesson dialogically and interactively. While in both the opening up phase of the lesson and the closing down phase multiple prompts were used to elicit learners' ideas, the dominant CA was different in these phases. In the "opening up" phase, these prompts were followed by further prompts, forming longer question chains in an IRFRF pattern (Mortimer and Scott 2003). In addition, the learners' answers were not evaluated or followed by explanations. These factors played a role in the dialogic CA applied in the opening up phase. This is in contrast with the closing down phase, where the prompts were followed by heuristics and explanations. Through these specific forms of guidance, the PSTs focused on the scientific view and aimed to consolidate it. This had an effect on the applied CA which was authoritative and interactive. The PSTs linked the dialogic opening up and authoritative closing down phases of the lesson together through pedagogical link-making which connected the learners pre-existing ideas to be connected with the findings from their investigations. The lesson had thus cumulative and meaningful structure where the learners were given a chance to investigate their own ideas in the Investigation phase and to understand that new information is built on top of pre-existing knowledge (Alexander 2006; Mercer 2008; Scott and Ametller 2007). These are features of learning about inquiry—that is, how scientific knowledge is constructed (Bybee 2000).

The analysis of the excerpts from this study make it clear that in-depth analysis of the provided guidance, which also takes into account the temporal properties (Lehesvuori et al. 2013) and pedagogical link-making (Scott et al. 2011), is needed to study the complex connection between the forms of guidance and the applied CA. The findings of this study have twofold implications regarding both research of guidance for IBL and teachers' practice. Regarding research, while the need for guiding or supporting IBL has been well documented in the literature, research has concentrated on the effect that providing different forms of guidance for IBL has on content learning outcomes (Alfieri et al. 2011; Lazonder and Harmsen 2016). The findings from the example lesson showcase the role that the presence or absence of different forms of guidance can have on planning and implementing meaningful science lessons where learners are given chances to share and make explicit their existing knowledge with others, conduct investigations to possibly challenge existing knowledge and make connections between their knowledge with the scientific view and understand the possible omissions in previous thinking (Scott and Ametller 2007). Research on how guidance for IBL can influence the use of epistemic practices of science through inquiry has been called for (Hmelo-Silver et al. 2007), and this paper sheds more light on this matter. Zacharia et al. (2015) gave some recommendations based on their literature review on how different phases of IBL should be guided to promote learning. The focus of their literature review was on guidance provided by software for IBL on lessons where simulations or online laboratories are used to conduct the investigations, such as in the case example lesson. Their recommendations include providing scaffolds and prompts in the Conceptualization phase and did not include providing direct information (i.e. explanations) in the Conclusion phase. The findings from this case example lesson complicate these recommendations: providing specific forms of guidance in the "opening up" phase (Conceptualization) and not providing them in the "closing down" phase (Conclusion) could have detrimental effects on the learners' ability to meaningfully connect their existing knowledge with the scientific view (Scott and Ametller 2007). This implication should be studied with more data from multiple contexts and also from in-service teachers' lessons.

Regarding teachers' practice, previous research has conceptualized a holistic model (Lehesvuori et al. 2011a) regarding implementing meaningful inquiry-based science lessons that include both a dialogic opening up phase and a more authoritative closing down phase. This model offers only limited tools for detailed lesson planning, which is essential for implementing inquiry in practice (Zubrowski 2007). The case lesson analysed in this paper provides an example on how different forms of guidance can have a role on implementing meaningful inquiry-based science lessons. By consciously providing prompts throughout the lessons and by providing specific forms of guidance only after the Investigation phase, the PSTs elicited learners' ideas throughout the lesson but provided the scientific view only after the learners have had a chance to investigate their existing ideas. Potentially, the results from this case example that connect the somewhat concrete typology of the forms of guidance by Lazonder and Harmsen (2016) with the more abstract typology of different CAs (Mortimer and Scott 2003) could give teachers new ways to plan lessons with differing CAs.

Limitations

The limited amount of data makes drawing broader conclusions challenging. The aim of this article was to study the role of guidance in building the CA applied in science lessons through both a theoretical overview and a fine-grained analysis of case example lesson by pre-service teachers. More research is needed to validate the findings from different grades and also from in-service teachers' lessons. Pre-service teachers' limited content knowledge could have an effect on their teaching, including the guidance they provided (Childs and McNicholl 2007). We also acknowledge that many other features, such as wait time, intonation or the use of personal pronouns, have an impact on the CA applied by teachers (Lehesvuori et al. 2017).

Funding Information This study was partly funded by the Technology Industries of Finland Centennial Foundation.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Research Involving Human Participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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