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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.

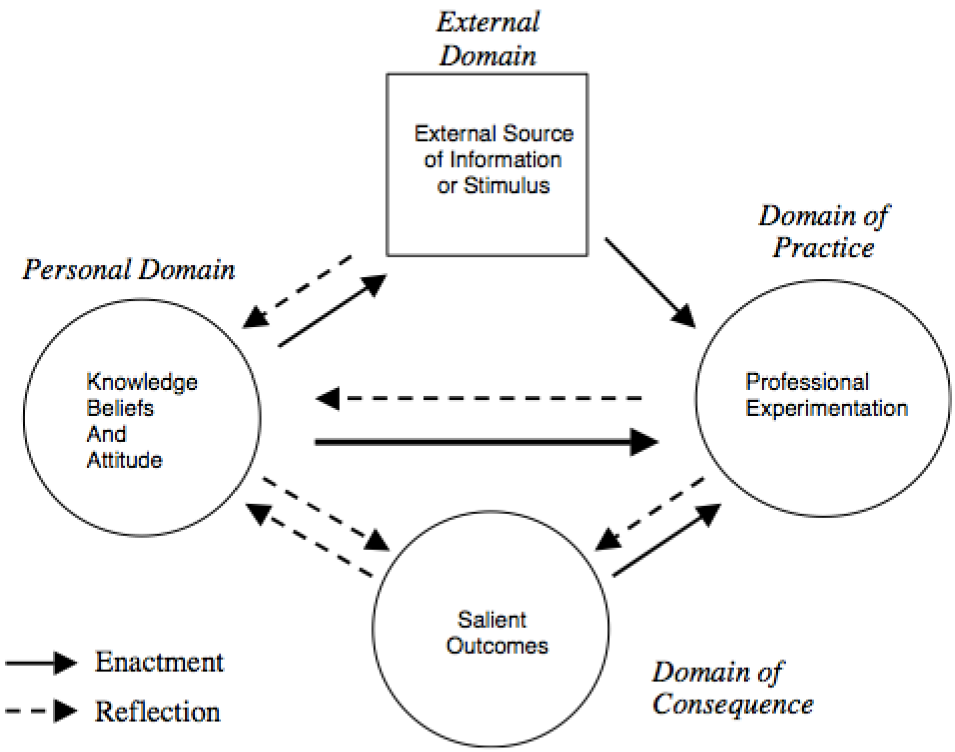

Figure 1. The Interconnected Model of Professional Growth by Clarke and Hollingsworth (2002).

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%

χ^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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