Developing a Collaborative Model in Teacher Education – An Overview of a Teacher Professional Development Project

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Abstract The article discusses the development of an educational model intended to support teachers' professional development in science education. In this research and development project, LumaLähetit, pre-service teachers, in-service teachers, and teacher educators formed teams to collaboratively plan teaching and produce material for inquiry-based and integrative science instruction in primary schools. The results are based on three design cycles of the model. Thus far, ten schools, 24 in-service teachers, 30 pre-service teachers, and 560 pupils have participated. The results, which are based on the qualitative content analysis of participants' open answers to a questionnaire, indicate that the developed collaborative model for science education supported pre-service teachers and in-service teachers' professional development in many ways. Several processes mediating the embodiment of the designed model were identified, especially during the second or third design cycles. Participants reflected on theory and practice. They experienced increased knowledge about inquiry and integrative approaches, collaborated in teams to some extent, and found this to be supportive during the project. Also, pre-service teachers appreciated the opportunity to teach in the schools. In general, careful goal setting, collaboration between the participants, and guidance by teacher educators during the initiation of the project were found to be crucial to the further success of the project. The results highlight a need for further research in order to better meet to the challenges of team teaching, inquiry-based instruction, and integrative teaching. The designed model was developed between the cycles and must be further developed in the future, especially in terms of supporting collaboration and clarifying theoretical concepts during the project.

Keywords: teacher professional development, team teaching, inquiry approach, integrative approach, science education

1 Introduction

In research-based theories of teacher education, research methodologies and practice are important parts of pre-service teacher preparation programs in Finland (Kansanen, 2006; Jyrhämä et al., 2008). In this approach, a major subject, methodological studies, and a relationship with the reality of school are emphasized. The aim is for pre-service teachers to obtain professional insights into education from several perspectives, including educational psychology and sociology, curriculum theories, assessment, special-needs education, and pedagogical content knowledge in selected subject areas (Sahlberg, 2011). According to the study of Jyrhämä, Kynäslahti, and Krokfors et al. (2008), pre-service teachers appreciate the research-based approach being used as the main organising theme of teacher education. The students' experienced that the research-based approach was realized to an especial degree in subject didactics, which included studies of pedagogical content knowledge for the school subjects taught in elementary school. However, the students' experienced that the research-based approach was not realized to as great a degree in practicums as in studies of subject didactics (Jyrhämä et al., 2008). Thus, combining educational theory and practice to a greater degree is needed in teacher education.

The research-based approach to teacher education is becoming even more challenging because the renewed core curriculum for basic education (Finnish National Board of Education, FNBE, 2014) emphasises, for instance, integrative, phenomenon-based, and project-based teaching. The goals of the curriculum require teachers to be able to apply research-based methodologies in practice. However, subject-divided courses within the university may make it difficult for pre-service teachers to form the coherent integrative views needed for integrative science teaching. Also, adapting an inquiry approach in science teaching can be difficult for many pre-service teachers because their own experiences of non-inquiry-based science learning have a major impact on their expectations of and approaches to learning to teach (see Loughran, 2014). Collaboration is a key component of teacher education in that it helps students to learn about successful teaching, as well as acquiring team teaching abilities (Wallace, 2003). Also, the new approaches emphasised in the renewed curriculum require teachers to plan, implement, and evaluate teaching together.

In sum, there is need for the researching and development of team teaching, inquiry-based, and integrative approaches within teacher education. In the education program for class teachers at the University of Helsinki, there are 15 ECTS for compulsory studies in science and environmental education. These studies include three courses: Biology and geography, Physics and chemistry, and Health education and discipline-based curriculum integration. Each of these is comprised of the basic didactics of various subjects. However, only the relatively brief focus on integrative unity allows students to learn how to implement integrative teaching and learning.

To promote the goals of teacher education and teaching in schools, both pre-service and in-service teachers' professional development must be considered. In order to be successful, *Teacher Professional Development Programs* (PDPs) must acknowledge that professional learning involves complex and iterative interactions between the teacher, the school, and the learning activity (Opfer & Pedder, 2011). When developing PDPs, it is thus important that developers recognise teachers as active agents who are responsible for their own professional development (Luft & Hewson, 2014; Wilson & Berne, 1999; Juuti et al., 2016). Juuti, Lavonen, and Meisalo (2016) propose using the framework of pragmatism to help researchers design educational innovations that take into account the challenges of adopting the innovations created by teachers in PDPs. According to the multinational Teacher and Learning International Survey (TALIS) (OECD, 2016), supporting teachers in their professional development is positively associated with their self-efficacy, as well as their satisfaction with their current work environments and the teaching profession. In particular, supporting peer networks and collaboration and providing opportunities to apply their learning to classroom practise are found to be important for teachers' professional development.

In this article, we describe a model for a professional development program for both students in teacher education (referred to as pre-service teachers in this paper) and in-service teachers. The goals of the professional development model are to promote an inquiry approach in science teaching, an integrative approach in science education, and team teaching. Our research question is as follows: According to pre-service teachers, in-service teachers, and teacher educators, how does the pedagogical model designed in this study support teachers' professional development in inquiry- integrative, and team teaching approaches in science teaching?

1.1 Inquiry approach

It is agreed that science education should involve an inquiry approach and scientific practices in order to promote students' scientific understanding and critical thinking (e.g., Crawford, 2014; Osborne, 2014; Furtak et al., 2012; Bransford et al., 2000, 25). By engaging students in scientific practises, such as asking questions, carrying out investigations, analysing data, and constructing and evaluating explanations, it is possible to promote students' procedural and epistemic knowledge, as well as their interest in science (Osborne, 2014). An inquiry approach is emphasized in the renewed curriculum for basic education (FNBE, 2014), especially in *Environmental Studies* (f. Ympäristöoppi) for the grades one to six.

Researchers have claimed that inquiry approach helps in promoting students' interest in science (Crawford, 2014), promoting an understanding of how science is done and what scientific knowledge is like (Minner et al., 2010), and encouraging the ability to make decisions related to controversial societal problems (e.g., Duschl et al., 2007; Sadler et al., 2007). Previous studies provide ample evidence that inquiry-based science teaching can

have positive impacts on students' learning of scientific concepts and understanding of the nature of scientific inquiry (see reviews in Minner et al., 2010; Crawford 2014). In Finland, based on a large amount of follow-up data on Finnish grade nine students, Uitto and Kärnä (2014) found that at the school level, teaching methods emphasizing an inquiry approach that is correlated strongly with students' performance in biology and positive attitudes toward biology as a school subject when the analysis was carried out using school-specific averages from a survey carried out in 97 schools.

Despite many arguments supporting inquiry approaches in science instruction, there have also been critical views. Kirschner et al. (2006) suggest that inquiry-based instruction that depends on students' self-guided discovery and minimal or non-existent instruction is not efficient and may lead to misconceptions. Also, Mayer (2004) questions "pure inquiry" in science classes and underlines the need for more empirical evidence when evaluating various teaching methods. Crawford (2014) emphasizes that even if the inquiry-based approach is regarded as beneficial by most researchers, more studies are needed that concentrate on the actual classroom activities used during inquiry-based instruction.

As in Crawford's (2014) definition, we consider the active role of students to be the key component of inquiry approaches. Student activities can be manifested in various ways: creating research questions, making hypotheses, carrying out investigations, interpreting and evaluating data, and making arguments. Only one aspect of the inquiry approach can be emphasised at a time, and it is not necessary and not always even possible to include every aspect in a short teaching sequence (cf. Osborne, 2014). The type of the inquiry can be confirmation-based, structured, guided, or open (see, for instance, Banchi & Bell, 2008). The use of inquiry approaches is not easily transferred into classroom activities. They can be promoted by providing teachers with multiple examples of inquiry activities, supporting them in planning long-term units, and providing opportunities for reflection on emerging practices (Crawford, 2004).

1.2 Integrative approach

In Finland, *Environmental studies* is an integrated subject group composed of biology, geography, chemistry, physics, and health education in the grades one to six (FNBE, 2014). Integrative science teaching is commonly argued for by stating that real-world phenomena are integrated in nature and that interdisciplinary learning contexts are thus authentic (Petrie, 1992). Czerniak and Johnson (2014) review empirical evidence of increased student knowledge and affective gains in integrated science and mathematics teaching as compared to traditional instruction.

According to the review of Gresnigt, Taconis, van Keulen, Gravemeijer, and Baartmand (2014), educators should recognize the various levels of integration. A *fragmented* approach means that different subjects are taught separately, while in a *connected* approach, a connection is made between the separate subjects. A *nested* approach is used when a skill or knowledge from one discipline is targeted within another subject, enriching

the teaching of that other subject. In a *multidisciplinary* approach, two or more subject areas are organised around the same theme or topic, but the disciplines preserve their own identities. In an *interdisciplinary* approach, there is a loss of the disciplines' individual perspectives, and skills and concepts are emphasised across subject areas. In a *transdisciplinary* approach, integration transcends individual disciplines and the focus is placed on the appropriate field of knowledge, as exemplified in the real world (Gresnight et al., 2014) when, for instance, sustainability issues are considered in teaching. In this case, a phenomenon, which can be an object, area or action in the school or a nearby area (a tree, forest, residential area, co-operation, a sustainable way to travel, etc.) is considered via ecological, social, and economic viewpoints. Different subject areas and learning environments are used to find answers to the questions posed. In general, interdisciplinary and transdisciplinary approaches are demanding for teachers, and to be successful, they require school-wide investment, curricular decisions and teacher training.

Hinde (2005) argues that in order for an integrative approach to be effective, the integrated activities should be educationally significant and meet the curricular objectives in all the merged content areas. Also, the activities should include authentic applications of skills from other content areas, as well as being developmentally appropriate for learners. Focusing on the integration of science and mathematics, Hurley (2001) found that integration can be defined at various levels. At the lowest level of integration, science and mathematics lessons are planned and taught sequentially. In simultaneous teaching, integrated science concepts and mathematics concepts are shown in parallel or partially or completely combined (Hurley, 2001).

To promote integrative science teaching, teachers should become familiar with curriculum recommendations, receive instruction in planning integrative units, and learn about resources and technological tools that support integration (Czerniak & Johnson, 2014). They should be aware of the various levels of integration (Gresnight et al., 2014). Mason (1996) emphasizes the importance of teamwork in teacher educational programs because collaborative processes are often necessary in integrative teaching.

1.3 Team teaching

According to the renewed basic education curriculum (FNBE, 2014), collaboration is emphasized in various contexts, for instance, between teachers, students, homes, and out-of-school actors. Team teaching is regarded as an important approach in meeting the collaborative goals of education. In general, team teaching can be defined as a pedagogical method in which two or more teachers teach a single group of students together, and it can be implemented in various ways (Davis, 1995). Team teaching can be divided into four distinct areas: planning, content integration, teaching, and evaluation (Davis, 1995, Baeten & Simmons, 2014, 93). Collaborative teaching has been found to help teachers learn from one another (Shibley, 2006), and such teaching encourages and motivates teachers´ professional development (Sandholtz, 2000; Birrell & Bullough, 2005). From students´

point of view, team teaching increases the number of opportunities for student-teacher interaction (Wadkins et al., 2006). Also, research indicates that team teaching has a positive impact on student learning outcomes (Little & Hoel, 2011). Teachers and schools that engage in high-quality collaboration have better achievement gains in math and reading (Ronfeldt et al., 2015).

In our project, collaborative teaching is the core of the action. In our study, team teaching means that teacher educators, in-service teachers, and pre-service teachers collaborate in various ways when planning teaching, carrying out teaching, and evaluating and reflecting on the theory-based goals of teaching and their own professional development. Team teaching can be implemented, for instance, as concurrent teaching among pre-service and in-service teachers.

2 Design of the model

In order to meet the challenges associated with teacher education, both pre-service and in-service, we designed a model for teacher professional development. The designed model combines pre-service education for students in teacher education with professional development for in-service teachers. The operational model was planned in the LumO resource centre in the Department of Teacher Education at the University of Helsinki. The pilot project began in 2014. Biology, chemistry, physics and mathematics teacher educators designed the initial model and the integrative themes, such as the *micro world, outdoor activities,* and *human health*. Hands-on materials were developed for each theme. *Microworld* included the cultivation of bacteria. *Outdoor activities* and *human health* included various materials and activities for observations, inquiries, and plays. The *LumaLähetit* model was included also in a larger project, *Koulutuksesta kouluun* (*From Training to Teaching),* and is part of a national LUMA-SUOMI development project.

The iterative development of the model can be characterised as design research, in which a new understanding of educational phenomena is developed while designing practical educational solutions (Edelson, 2002). Edelson suggests that design research aims to produce new knowledge of theoretical concepts, knowledge of successful design process, and knowledge of successful design solutions. In our research, we study how the challenges in teacher education can be met by supporting the collaboration of pre-service teachers, in-service teachers, and teacher educators with the designed professional development model. Our objective is to design a successful model while acquiring a theoretical understanding of how pre-service and in-service teachers perceive their professional development and how the teacher educators perceive the development of the model in relation to inquiry-based, integrated science teaching and team teaching.

Design research has been criticized for lacking methodological rigor and clear standards (Dede, 2004; Kelly, 2004), as well as lacking credibility in its claim to simultaneous design evaluation and theory building (Phillips & Dolle, 2006). Sandoval (2014) proposes conjecture mapping as a methodological approach to design research in order to address

these methodological concerns. A conjecture map helps to articulate how the theoretical conjectures of the designed model are embodied in practise and how the embodied practises lead to desired outcomes through mediating processes. Sandoval (2014) suggests that in order to validate the outcomes of the specific design, e.g., the desired changes in educational practices, research projects must first document and explicate the mediating processes that leads to these outcomes. In Figure 1, we present a conjecture map, including our theoretical conjectures and their embodiment in our professional development model, as well as the initial mediating processes. The observed mediating processes are documented later in this article, followed by a discussion of the requirements of developing the model.

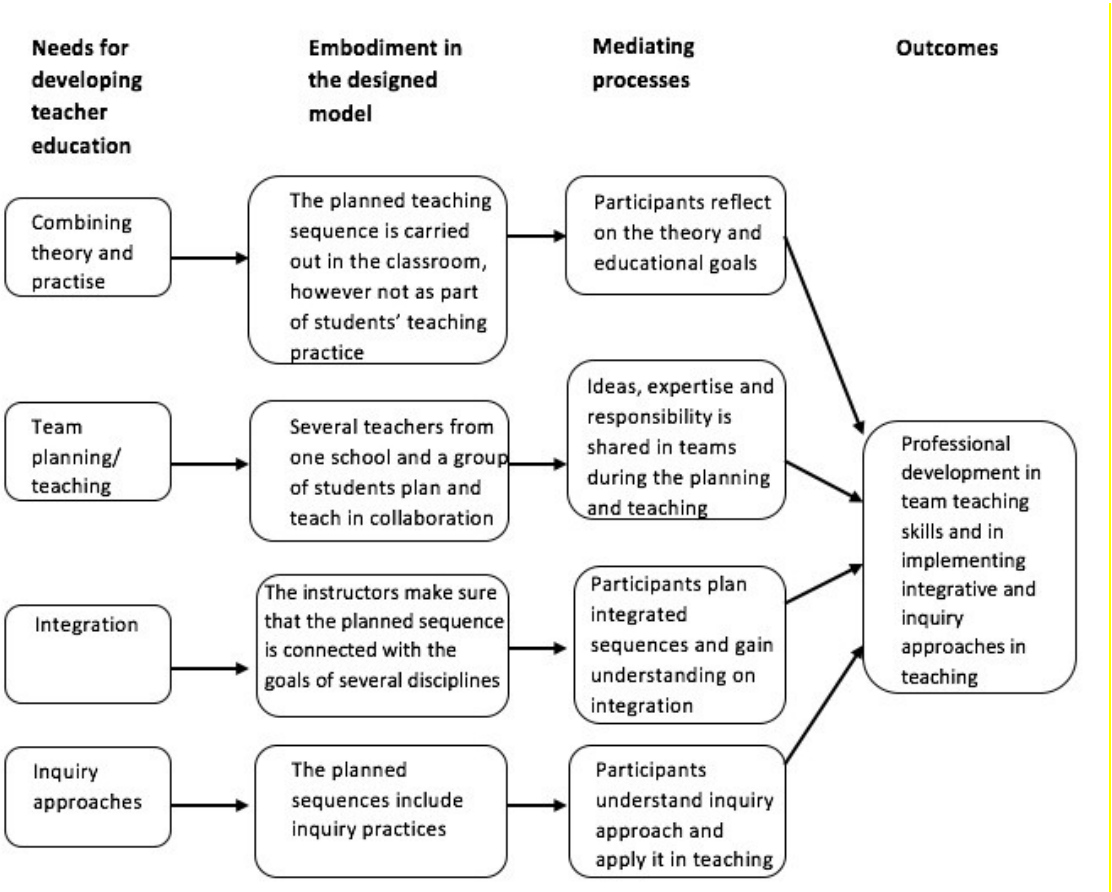

Figure 1. The initial conjecture map of the design to promote teacher professional development.

In this research and development project, *LumaLähetit*, we have designed a teacher professional development model to promote pre-service teachers', in-service teachers', and teacher educators' abilities to collaboratively plan and develop science teaching and product material for inquiry-based and integrative science instruction. One important objective is to support participants in sharing their expertise as equally important team members.

In the designed model, students, elementary school teachers, and teacher educators form teams that collaboratively apply the chosen theme for a specific school and plan the instruction (Figure 2). The initial PDP consisted of four phases: 1) the orientation of pre-service teachers, 2) the planning of the teaching sequence in teams of two to three pre-service teachers, two to three in-service teachers from the same school, and a teacher educator, 3) the implementation of the planned teaching sequence in the schools, and 4) reflection and evaluation on the process and sharing experiences by the participants. The teaching sequence to be planned is from three to eight lessons in duration and, according to the team's choice, can be carried out with more than one class attempting it at the same time or repeated with different classes.

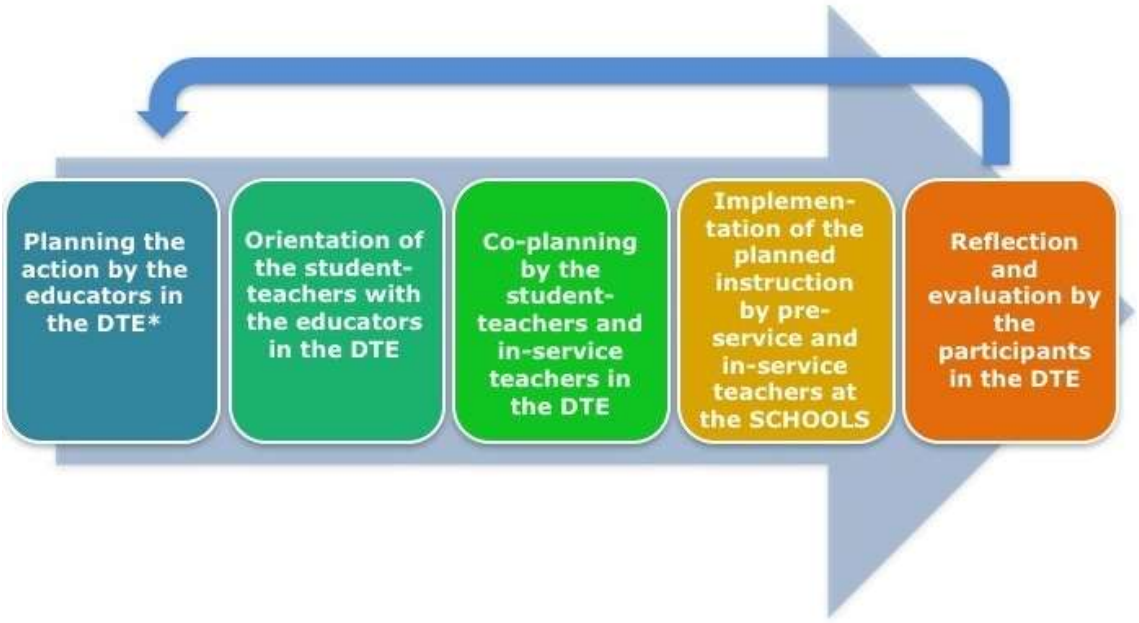

Figure 2. The model designed for the project. *DTE = Department of Teacher Education.

During the orientation of the pre-service teachers and the beginning of the cooperative planning, participants are briefly introduced to the theoretical aspects of inquiry-based approaches and integrative science teaching. Teams begin the planning of the teaching sequence with a certain theme or idea the in-service teachers with to introduce. They are encouraged to integrate more than one discipline and include inquiry approaches. Our aim is that pre- and in-service teachers, as well as teacher educators, all become active participants in planning the teaching sequence (cf. Juuti et al., 2016; Biesta & Burbules, 2003). Whereas pre-service teachers have fresh ideas about the latest educational practises, in-service teachers have ample knowledge of pedagogical practises in everyday school life, especially concerning the pupil group in question. Teacher educators, who tutor the teams, bring up ideas about the above-mentioned goals, as well as providing ideas and material for the classroom activities.

3 Methods

By the spring of 2016, three cycles of the PDP model had been carried out. In all, ten schools, 24 in-service teachers, 30 pre-service teachers, and 560 pupils have participated. One school has participated three times, one school has participated twice, and five teachers have participated twice (Table 1).

The pre-service teachers participated in the project voluntarily; in 2014, they also received a small monetary reward, and in 2015 and 2016, this project was presented as an alternative way of completing a compulsory course in their teacher studies. The schools, all situated in the Helsinki region in Southern Finland, and in-service teachers also participated in the project voluntarily.

Table 1. Number of participating schools, in-service teachers (referred to as teachers), and pre-service teachers (referred to as students) during the first three cycles in primary schools.

N	Fall 2014	Spring 2015	Spring 2016	Total
Primary schools	5	4	4	10
Pupils	233	201	150	584(1
Class teachers	12	10	8	30(2
Class teacher students	4	9	8	22
Subject teacher students	3	5		8

1.One school participated twice, another participated three times
2. Five teachers attended twice

During the reflection meeting, at the end of each cycle, the pre-service teachers, in-service teachers, and teacher educators shared their experiences and evaluated the entire process, including the actual classroom activities. After each cycle, pre- and in-service teachers answered a questionnaire about how they experienced the project, what they appreciated the most, and whether they experienced professional development. Between the second and third cycles, the teacher educators were asked, via a questionnaire, about their experiences in developing the model and participating in the PDPs. Their answers were analysed qualitatively via inductive content analysis (c.f. Elo & Kyngäs, 2008). The answers were coded, using the sentence as the analytical unit. The coded answers of the pre- and in-service teachers were categorized into three groups (professional development, collaboration, and general views on the project), and the answers of the teacher educators were categorized into four groups (inquiry, integration, collaboration, and improving the model). The quantities of the pre- and in-service teachers' similar experiences were counted for each PDP cycle.

In this study, we analysed only the questionnaire data collected from the participants. Also, the reflection meetings at the end of each cycle were recorded. However, for the purposes of this study, the reflection meetings serve only as a part of the PDP-model rather than research data.

4 Results and Discussion

4.1 Teachers and teacher students

The questionnaire was answered by five pre-service teachers (PSs) and two in-service teachers (ISs) after the first cycle, by ten pre-service teachers and seven in-service teachers after the second cycle, and by seven pre-service teachers and five in-service teachers after the third cycle. During the three cycles, altogether, 22 pre-service and eleven in-service teachers responded. Three of the in-service teachers attended and responded twice. In the analysis, we found three main categories and several subthemes concerning participants' perceptions of the project and its effects. These categories are listed in Table 2, and representative examples of the answers (translated from Finnish) are provided below.

Most participants developed professionally in some way after every cycle. Most commonly, they mentioned that their knowledge and courage to apply hand-on materials had increased; they gained the knowledge and courage to apply hands-on teaching, experimental teaching, or inquiry-based teaching; or they gained new ideas for teaching activities in general.

> *I was encouraged in using experimental and inquiry-based teaching methods. (PS)*
> *[The project] reminded me of the importance of experimental activities. (IS)*
> *Both students and teacher developed new ideas and had experiences in organizing hands-on learning. (PS)*

Many pre-service teachers also found teaching in authentic classroom settings to be rewarding in itself.

> *Combining practise and theory [was useful]. (PS)*
> *I had experience working with pupil groups. (PS)*

Collaboration within the teams was highlighted in the answers. Several participants mentioned positive experiences in terms of participating in teamwork or learning from it.

> *Being able to participate in multi-professional collaboration brought a new perspective and ideas. (PS)*

However, most pre-service teachers found that collaboration with teachers did not work as well as it should have, and the majority of the positive experiences in the collaboration were related to team planning and team teaching with other pre-service teachers.

> *The integration of class teachers into the project should be developed. (PS)*
> *Practising collaboration with other students [was useful]; collaboration with teachers was difficult. (PS)*

Some in-service teachers mentioned collaboration within the school as a positive experience.

> *It was nice to collaborate with parallel classes. (IS)*

Participants also evaluated the project on a more practical level. In general, the project was perceived to be a positive experience. Most in-service teachers and some pre-service teachers mentioned that the pupils showed great excitement and motivation during the teaching.

> *The pupils had wonderful experiences and became enthusiastic about making inquiries. (IS)*

Some pre-service teachers found managing schedules to be difficult and found that the project was too time-consuming, whereas some in-service teachers mentioned that the contribution of pre-service teachers, the provided equipment, and the time allocated to planning enabled novel ways of teaching.

> *The project made it possible to try new things. (IS)*

The goals of the project were mentioned as being unclear during the first two cycles.

> *The goals of the project were clear in the introduction, but after that, they were vague. (PS)*

However, the results indicate that the goals and approaches of the model were clarified during the cycles. In addition to the above-mentioned comments, two pre-service teachers questioned whether the project would have a sustained influence on the schools.

Table 2. Key categories of pre-service (PS) and in-service (IS) teachers' experiences in the project during the first three cycles.

Participants' experiences in the project, 2014–2016						
	First cycle		*Second cycle*		*Third cycle*	
Theme	Pre-service teachers 5*	In-service teachers 2*	Pre-service teachers 10*	In-service teachers 7*	Pre-service teachers 7*	In-service teachers 5*
Professional development						
Courage to pursue and knowledge on IBL and hands-on activities increased		2	9	6	6	2
Gained ideas for learning activities	2	1	7	6	5	1
Experience in teaching	2		5		6	
Knowledge and experience of integration			1	1	3	1
No experienced change in teaching methods			2			1
Collaboration						
Positive experience during collaboration in teams	4	2	7	3	6	5
Collaboration with teachers should be further promoted	4		6	1	4	1
Positive experience during collaboration inside schools		2		2		
General views on the project						
Positive learning experiences in classrooms	5	2		4	2	4
Difficulties in managing schedules	4		2	1	1	2
Much work for the credits or relative to expectations	2		3			
Additional resources in schools		1		3	1	
Goals of the project should be clearer	2		1			
Ensuring continuity in schools is problematic			2			
Integration should be promoted				1		
Connections to schools were formed			1			

* number of answers from students or teachers

In general, the feedback was positive (Table 2). However, there are clear differences between the first and subsequent cycles. Most pre-service teachers attending the first cycle felt that they had difficulties in managing their schedules, and some felt that there was much work for the credits or relative to the expectations of the university. The project objectives were better achieved during the successive cycles, especially when considering pre-service teachers' conceptions of their professional development. More than half of the participants felt that they received the courage, knowledge, and ideas needed to use an inquiry approach and hands-on activities in teaching. Knowledge and experience of

integration increased gradually. In the third cycle, half of the pre-service teachers felt that they had received knowledge and experience of integration. Most participants also reported positive experiences of collaboration in teams. Specifically, most of the pre-service teachers believed that collaboration with in-service teachers should be further promoted. In general, pre-service teachers had positive experiences in all cycles (Table 2).

4.2 Teacher educators

Before the third cycle, seven teacher educators had been developing the project and participating in it as instructors and tutors. Each of them answered to a questionnaire about how they perceived the project and how the model needed to be developed.

The teacher educators found that the project has succeeded in elaborating inquiry-based teaching excellently (4 answers) or to some extent (2 answers). Integration was found to have been realized excellently (4 answers) or to some extent (2 answers). A need to improve these themes was also mentioned (2 answers).

> *During the second round, integration too often depended on the teachers allocating more time for the theme than originally planned.*

Similar answers were given concerning the degree to which team teaching between pre-service and in-service teachers succeeded. Four participants found that team teaching has worked out excellently, two found that it has worked out to some extend and according to two it needs to be improved. Participants were also asked about their views on the progression of the project. Three participants mentioned the content, one mentioned the wholeness of the project, and one mentioned the personal aspect of the project as having improved the most. The teacher educators also highlighted the experience of development between the first and second cycles.

> *The model has become clearer, and the focus has changed from developing the material to developing the entire collaborative structure.*

According to the feedback from the educators, much work was done in the first cycle of the model to plan the project as a whole, including its activities, time schedules, collaborations, etc. Thus, for the educators, the first cycle was the most laborious. However, the model was considered useful for planning and implementation.

When asked about how the project should be improved, the answers varied (Table 3). According to some teacher educators, the most attention should be paid to promoting integration and team teaching. According to two respondents, the model must be developed generally. It was also suggested that it if more theoretical background for the initial instruction of the participants were included, this would be helpful.

Table 3. Teacher educators' perceptions of how the project should be improved.

More time for the planning	More focus for the timing	Team teaching	Integration	Inquiry approach	Teacher students should be able to more easily enter the course	Extension	Cannot say
2*	2*	3*	4*	2*	1*	1*	1*

* Number of teacher educators. Seven teacher educators answered in total.

Although the teacher educators had many suggestions regarding teaching, they also gave the pre-service and in-service teachers the opportunity to make their own pedagogical decisions. However, some in-service teachers believed that the pre-service teachers were given too much responsibility for the teaching, so the idea of team teaching was not implemented properly (Tables 2 and 3). Some educators also believed that integration was not taken into account sufficiently. This is in line with the pre-service teachers' feedback during the project: only in the third cycle did most pre-service-teachers give independent feedback that they had truly learned about integration. In general, the multiple goals of the designed model were reflected in the answers because some teacher educators emphasised some aspects of the model more than others.

4.3 Developing the model

According to Sandoval (2014), in design research, mediating processes leading to the goal outcomes must be documented and explicated. The embodiment of the design objectives in the designed model can then be modified during the study to better reach its goals. In our study, an initial conjecture map was developed (Figure 1) and used to explicate and study the mediating processes. A professional development model was designed combining pre-service teachers, in-service teachers, and teacher educators in collaborative teams that aimed to develop comprehensive science education in schools (Figure 2). Several mediating processes could be identified in the study, especially during the second and third design cycles. For instance, participants experienced increased knowledge about inquiry and integrative approaches, they collaborated in teams to some extent and found this to be supportive of the project. The pre-service teachers appreciated the opportunity to teach in the schools, and to some extent, participants reflected on the theoretical goals of the project. The model was developed between the cycles according to the observed mediating processes and will be further developed in the future.

4.3.1 Theory and practice in the introduction

Understanding the goals of the project is, of course, crucial to its success. Thus, the introduction of the project is very important mediating process. It is important that the pre-service and in-service teachers are well aware of the theoretical background of the relevant pedagogical issues: collaboration, team teaching, inquiry, and integrative approaches in education. In our project, the introduction seemed to have been crowded with information, and indications suggest that the time provided to orient oneself to the project may have

been too short, at least during the first two cycles (Table 1). The goals of the project were articulated more clearly during the second and the third cycles when recruiting participants and during the introduction day. More attention was also paid to describing the pre-service teachers, the project, and the amount of work required.

However, in future cycles, more attention must to be paid to the introduction of the project, specifically to better explaining the relationship between theory and practice in the project. One option is that the pre-service teachers and in-service teachers study the theoretical viewpoints, such as team teaching, integrative, and inquiry approaches, independently before starting the project. After these introductory studies, the pre-service teachers may meet with the teacher educators once to decide the frames and goals of the teaching. After these preceding activities, all participants can meet during the introduction (Figure 2). The use of introductory study material before beginning the project was suggested, for instance, as webinars and a summary of main ideas. Very detailed material is not appropriate, because in-service teachers are experts in teaching and pre-service teachers have recently learned about the topics of the project in their studies. In any case, the clearer guidance of teacher educators seems to be essential in the beginning of the project. During the reflection and evaluation phase, the theory involved in the project must be scrutinized again, and the participants must be given time and space to reflect on it.

4.3.2 Tackling with collaboration and team teaching

Because of the structure of model, team teaching was taken for granted during the first cycle. Collaboration among the participants was found to be very important (Table 2). Consequently, team teaching received more attention during the second and third cycles. For the third cycle, the model was modified to include an early meeting between pre-service teachers and in-service teachers, which allowed them to begin co-planning (Figure 2). However, it became evident that the idea of team teaching was still not fully manifested in the participating schools, and the need to promote collaboration between pre- and in-service teachers was also brought up after the third cycle. It seems that the early collaborative meeting among the participants alone is not enough to support active collaboration during the project. The limited time and resources for planning teaching in schools may restrict teachers' communication and co-planning during the project. This indicates that in our model, collaboration and team teaching must be very carefully emphasized so that all participants are well-aware of the concepts and committed to putting them into action. The participants should be provided with clear instructions about their collaborative roles within the team. In addition, allocating resources to teacher planning during the project is worth considering for the next cycles (cf. Lavonen et. al., 2006).

It was suggested that the pre-service teachers should first meet without the teachers, as in the first and second cycles. This may indicate that some of the pre-service teachers lacked the expertise needed for collaborative planning (e.g., knowledge of the science theme). In order for the pre-service teachers to be able to share their expertise as equally important

team members, an orientation phase for them alone may be needed. Alternatively, orientation may also take place through preliminary self-study material regarding the goals and concepts of the project.

4.3.3 Inquiry and integrative approaches

An integrative approach was included in the project during the first cycle so that hands-on material on a specific integrative theme (*Microworld, Outdoor activities,* and *Human health)* could be developed. During the second and third cycles, pre-service and in-service teachers were encouraged to apply the previously prepared material to new learning contexts in order to promote integration. In the third cycle, a new *Electricity* theme and related material were developed. Inquiry approaches were often mentioned in the answers after the first cycle (Table 2), indicating that the participants had experiences in using the inquiry approach. However, whether the participants were aware of the various levels of the inquiry approach was not evident (Banchi & Bell, 2008).

The integrative approach was not brought up in the participants' comments during the first and second cycles. Thus, the model was modified to focus more attention on integration in the beginning and during the third cycle. This emphasis resulted in several notions of integration by the participants (Table 3). However, in the data, it is not clear whether the participants were aware of the various levels of integration (Gresnight et al., 2014).

Several modifications to the theoretical conjectures must be considered in future cycles (Figure 1; see Sandoval, 2014). It is important to pay more attention to and allocate more time and resources to grasping the idea of team teaching and supporting collaboration within teams. The goals and approaches must be very carefully explained to and agreed to among the participants. Teacher educators must pay more attention to the goals during the project so that the relationship between theory and practice is considered more intensively. The theoretical background on the inquiry approach and integrative approach and their various levels must be better clarified in the introduction and throughout the project.

5 Conclusions

Our objective in designing this model for teacher professional development was to meet challenges in teacher education related to teachers' inadequate skill in team teaching, integration, and an inquiry approach to science teaching. In general, the pre-service teachers found that the research-based approach was not very well-realized in the teaching practicum (see also Jyrhämä et al., 2008). The essential aspect of our designed model is that after a well-planned initiation, including guidance by teacher educators, pre-service teachers and in-service teachers form teams and collaboratively develop new ideas to implement a short science teaching sequence based on the theory of inquiry-based and integrative approaches. According to the results, this kind of model seems to have significant potential to develop team teaching skills, as well as an understanding of and the

courage to pursue an inquiry approach and integration in science teaching. When combined with students' pedagogical studies, these students may develop an increased understanding and higher self-efficacy in using a research-based approach in their coming teaching practicums.

Our finding that collaboration was highly emphasized by the participants in the professional development project is in line with previous studies that highlight the importance of an active role on the part of teachers in professional development programs and providing chances for collaboration and the sharing of ideas (e.g., Juuti et al., 2016, Luft & Hewson, 2014; OECD, 2016; Wilson & Berne, 1999). This study indicates that when developing teacher education and professional development, it is necessary to pay particular attention to creating concrete opportunities for collaboration and supporting teachers in these collaborates.

In terms of an integrative approach and an inquiry approach in science teaching, it is important to provide participants with theoretical tools and guidance for planning the activities and reflecting on the implementation.

As for the inquiry approach, it is essential for the participants to recognize different types of inquiry approaches, namely confirmation, structured, guided, and open inquiry, in planning and teaching (c.f. Banchi & Bell, 2008). Similarly, regarding integration, it is essential to understand the different levels of integration, from connected to transdisciplinary approaches, along with their cognitive, affective, skill, or competence goals (Gresnigt et al. 2014). In order for this to occur, a thorough introduction to PDPs is essential.

In the future, the main objectives in designing this model should be ensuring collaboration and participants' reflection on inquiry approaches and integration in teaching activities. In order to better understand the underlying processes that define the realization of these objectives, the teams' planning meetings, as well as the introduction and reflection sessions, should be studied in more detail.

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