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Preparing teacher students for 21st century learning practices (PREP 21): A framework for enhancing collaborative problem solving and strategic learning skills

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Abstract

With regard to the growing interest in developing teacher education to match the 21st century skills, while many assumptions have been made, there has been less theoretical elaboration and empirical research on this topic. The aim of this article is to present our pedagogical framework for the 21st century learning practices in teacher education. We will first review the current status of policy frameworks for the 21st century learning skills. Based on our previous work and current understanding in the field of learning sciences, we will next elaborate the processes and strategies for collaborative problem solving skills and strategic learning skills to specify current, rather general claims presented regarding the discussion on 21st century skills. We will also provide concrete case examples facilitating strategic learning skills, collaborative problem-solving skills and the skills to use ICT (Information and Communication Technologies) in contexts of our previous studies.

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1 Introduction

Success in life and work in today's knowledge society calls for 21st century skills, i.e., skills for learning, creative and critical thinking, collaboration, and the ability to utilize ICT (Information and Communication Technologies) in these areas (Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci, & Rumble, 2012). It is assumed that upon embarking on their university studies, pre-service teachers have strong experiences of self-discovery, inquiry-based approaches, and critical thinking that they have adopted while using the Internet. Hence, it is often assumed that they should be able to face the challenges of the life-long and life-wide learning of a learning society and future schooling.

However, today's student population is not a homogeneous group, which raises challenges for teacher education. On the one hand, the current pre-service teachers can have a strong potential for critical thinking and collaboration. On the other hand, not all of these students are necessarily ready to be part of an inquiry-based, collaborative learning culture. Many students are the result of traditional school culture which strongly influences their assumptions regarding good teaching models, i.e., models featuring a traditional teacher-led approach (Mäkitalo-Siegl, Kohnle, & Fischer, 2011; Schratzenstaller, 2010; Webb & Mastergeorge, 2003). Hence, there is a need to develop new teaching methods and assessment tools in order to better equip citizens to be able to function in this knowledge society (see Krokfors, Kynäslahti, Stenberg, Toom, Maaranen, Jyrhämä, Byman, & Kansanen, 2010; Välijärvi, 2011). We believe that teacher education could be a powerful channel for triggering long-term change in the field. In order to trigger change in schooling, pre-service teachers first need to learn how to adapt to the new learning culture by themselves as students.

The foundational underpinning in our research is the socio-cognitive model of learning (Zimmerman, 2010) that emphasizes learning as a complex metacognitive and social process involving adaptive thinking, motivation, emotion and behavior. Accordingly, we view learners as active agents who can take control of their own learning processes, but also facilitate the others' learning (Sawyer, 2014).

One of the most well-known learner-centered pedagogical approaches is the one of inquiry-based learning. Earlier studies have indicated variation in inquiry-based pedagogical approaches and mixed results on the effects of inquiry-based learning (Casotti, Rieser-Danner, & Knabb, 2008; Hmelo-Silver, Duncan, & Chin, 2007; Loyens, Kirschner, & Paas, 2010; Rybarczyk, Baines, McVey, Thompson, & Wilkins, 2007; Wilhelm, Sherrod, & Walters, 2008). Hence, there is a need for a systematic scientific approach in order to measure the impact of instruction based on inquiry in education. Furthermore, more research is needed for developing theoretical understanding of inquiry-based learning models and their practical implementation among pre-service teachers being in a central role in developing future schooling.

With regard to the growing interest in developing teacher education to match the 21st century skills, while many assumptions and claims have been made (Binkley et al., 2012; Voogt & Pareja Roblin, 2010), there has been less theoretical elaboration and empirical research on the role of strategic learning skills and collaborative problem solving as a part of inquiry-based pedagogical designs. We will answer these challenges by developing a theory-based pedagogical framework, driven by socio-cognitive approach to learning, which aims to promote pre-service teachers' 21st century learning skills as part of our research project "Preparing teacher students for the 21st century learning practices". This framework will be utilized in our future research designs. The aim of this article is to outline the pedagogical designs for learning practices in which the central elements are strategic learning skills,

collaborative problem-solving skills, and the skills to use ICT. For grounding the arguments, we will first review and discuss the current status of policy frameworks for the 21st century learning skills. Based on our previous work and current understanding in the field of learning sciences, we will next elaborate the processes and strategies for collaborative problem solving skills and strategic learning skills to specify current, rather general claims presented regarding the discussion on 21st century skills. Then, we will present our pedagogical framework for the 21st century learning practices in teacher education. And finally, we will provide concrete case examples facilitating these skills in contexts of our previous studies.

2 What Are the 21st Century Learning Skills? – A Critical Examination

The issue of skills needed for the 21st century has been the subject of educational policymaking and research for over a decade; the skill sets have been defined in various educational initiatives, including in the US, Australia, Japan, England, and Northern Ireland, as well as by the European Union and the OECD (see Binkley et al., 2012).

In what follows, we present four comprehensive frameworks (See Appendix 1). The European Union has identified eight areas of key competences for lifelong learning, and the scope of each is precisely defined under the broad themes such as: learning to learn, communication, mathematica, scientific and technological competence, digital competence, cultural, social and civic competences and initiativity and enterpreneurship (Gordon, Halász, Krawczyk, Leney, Michel, Pepper, Putkiewicz, & Wiśniewski, 2009). As part of the international research project "Assessment & Teaching of 21st Century Skills" (ATC21S), a large group of researchers defined 21st century skills as *ways of thinking*, *ways of working*, *tools for working*, and *living in the world* (Binkley et al., 2012). In the US, the Partnership for 21st Century Skills, a joint government-corporate organization, has devised its own definition

of 21st century skills. According to their website, the skills are as follows: core subjects and 21st century themes, life and career, communication, collaboration, creativity, critical thinking, and information, media, and technology skills (P21Skills, 2013). The OECD has formulated its own version of 21st century skills and competences through the Definition and Selection of Competences (DeSeCo) initiative, which also underpins the OECD Programme for International Student Assessment (PISA). According to DeSeCo, the skills were structured under broad themes such as: information as a product and as a source, effective communication, ethics and social impact dimension of communication (Ananiadou & Claro, 2009). Overall, economic and societal changes closely related to recent developments in technology and consequently in the characteristics of jobs and the home environment seem to be regarded as the most important drivers of demand for 21st century skills (Voogt & Pareja Roblin, 2010).

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However, critical thinking, creativity, and even information literacy are not skills unique or specific to this century; they have been important human skills for thousands of years (Rotherham & Willingham, 2009). What is actually new is the extent to which changes in the global and national economy mean that collective and individual success depends on having such 21st century skills (Rotherham & Willingham, 2009). Moreover, it is well known that these skills are not separate from content but are always connected with subject matter (Silva, 2009). This raises the question about the role of the school and teacher education in students' learning of these skills. Indubitably, we know much less about how to teach collaboration, creativity, and innovation than about how to teach mathematics or languages, for instance.

Furthermore, many of the areas recognized in the frameworks of 21st century skills are not new as research areas either. Long-term research has already been conducted for decades on many of these areas, including self-regulated learning (Zimmerman, 2008), strategic learning skills and metacognition (Winne & Hadwin, 1998), and the process of collaborative learning (Barron, Pea & Engle, 2013; Paus, Werner, & Jucks, 2014; Stahl, 2013). For this research, we have operationalized the 21st century learning skills particularly a) from collaborative learning research and b) from a self-regulated learning perspectives. Next, we will further elaborate what these areas are and why they are important before introducing the pedagogical framework for the teacher education context.

3 Why Collaborative Learning?

To succeed in the knowledge society, learners and knowledge workers need to (more often and more effectively) combine their expertise and ideas in various collaborative situations, solve problems, and create new information and knowledge. Both formal training settings and everyday learning environments require the use of social skills and the ability to commit to coordinated work with co-learners. The following three sides of collaborative learning are represented in our approach: (1) collaborating to learn (collaborative learning environments to trigger productive learning mechanisms); (2) learning to collaborate (collaboration skills as such); and (3) learning to teach by applying collaborative learning approaches. It is further argued that it is especially critical to apply collaborative learning in the context of teacher education. Applying new pedagogical approaches in teaching and changing the ideas, thoughts, and habits about teaching and learning is challenging because there is a long history of teacher-led approaches (Bakkenes, Vermunt, & Wubbels, 2010; Mäkitalo-Siegl et al., 2011). Also recent research has shown that Finnish secondary school students (aged 11 to 15

years) rank collaboration the highest in importance among listed 21st century skills (Ahonen & Kinnunen, 2014). In addition, a quarter of those students mentioned social skills as the most important things they had learned in life so far. For these reasons, the "learning to collaborate" aspect is advocated as highly important among pre-service teachers in order to develop collaboration skills and the capacity to collaborate also among their future students in the schools.

Why is collaborative learning then beneficial in terms of learning? At its best, collaborative learning can foster productive interactions and learning activities, such as questioning, explaining and justifying opinions, articulation, argumentation, and elaboration (Häkkinen, Arvaja, Hämäläinen, & Pöysä, 2010; Mäkitalo-Siegl, Stegmann, Frete, & Streng, 2012). Our current understanding of collaborative learning leans on analysing interactions as a means of gaining insight into the social and cognitive processes of collaborative learning (Barron, 2003; Dillenbourg, 1999). Furthermore, knowledge sharing is an important construct to be used to understand the relationship between individual knowledge construction and how the participants share knowledge and create joint understanding (Jeong & Chi, 1997; Roschelle & Teasley, 1995). It has been suggested that collaborative learning takes place through processes of shared meaning-making when there is a dynamic relationship between shared meanings and individual interpretations. Through this process learners verify and negotiate their individual views in order to reach shared understanding or group cognition (Stahl, 2005). According to Schwartz (1995), the power of collaborative learning comes from the effort necessary for the group to build a shared understanding.

Several studies have also shown the other side of the coin. A high-level collaboration does not happen naturally; people vary in the extent of their capability to collaborate with each other. Various kinds of problems have been realized in collaborating in authentic educational settings. Researchers have shown that when learners are left on their own, they

rarely engage in productive interactions and knowledge-generative activities, such as asking each other questions, explaining and justifying their opinions, articulating their reasoning, or elaborating and reflecting upon their knowledge (Kobbe, Weinberger, Dillenbourg, Harrer, Hämäläinen, Häkkinen, & Fischer, 2007). Many things can go wrong in collaboration, and cognitive, motivational, and socio-emotional challenges may emerge (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006) even when the group activity is carefully pedagogically designed (Kirschner, Sweller, & Clark, 2006). Cognitive challenges may derive from difficulties in understanding one another's thinking or negotiating of multiple perspectives (Kirschner, Beers, Boshuizen, & Gijselaers, 2008; Mäkitalo, Häkkinen, Leinonen, & Järvelä, 2002). Motivational problems, in turn, can emerge due to differences in group members' goals, priorities, and expectations (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Järvelä, Järvenoja, & Veermans, 2008). If collaboration is not supported well enough and/or students do not have adequate skills, productive learning does not take place and students might end up with negative learning experiences (Farrell & Farrell, 2008; Häkkinen et al., 2010; Rajuaan, Beijaard, & Verloop, 2008). In sum, earlier research studies have recognized a need for supporting challenging factors of collaboration in their cognitive, motivational, and emotional regulation targets of group processes.

3.1 Collaborative Problem Solving (CPS) as a Way of Working

Problem solving as a specific form of collaboration has gained increasing interest due to recent educational policy initiatives. Collaborative problem solving will be assessed in the large-scale international assessment, PISA 2015 study (http://www.oecd.org/pisa/). In this context it has been defined as follows:

> Collaborative problem solving competency is the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution (OECD, 2013).

Especially complex problems require approaching a problem responsively by working together, exchanging ideas, and managing conflicts. The following three major competences are to be assessed in PISA 2015: (1) establishing and maintaining shared understanding and mutual knowledge; (2) taking appropriate action to solve a problem (task behaviour); and (3) establishing and maintaining group organization (organization/management).

Collaborative problem solving leans on various social and cognitive skills that have been defined in the ATC21s project (Assessment and Teaching of 21st Century Skills; Griffin, Care, & McGaw, 2012). The five broad strands of CPS are as follows: (1) perspective taking (the ability to take the others' perspectives into account); (2) participation (readiness to share information and externalize thoughts); (3) social regulation (awareness of the strengths and weaknesses of group members); (4) task regulation (planning and monitoring skills for developing strategies for problem solving and shared problem representation); and (5) knowledge building (the ability to learn and build knowledge through group interaction). These are the prerequisites for successful collaborative problem solving and are utilized in our pedagogical approach for teacher education practices.

3.2 Strategic Learning Skills as Ways of Thinking

Considering the opportunities and challenges of collaborative learning and problem solving, we will complement the pedagogical approach with current understanding of self-regulated learning, especially socially shared regulation of learning in collaborative contexts. In addition to identifying the critical processes of collaborative learning in terms of task- and content-related interactions, our focus is also to emphasize the pre-service teachers' individual learning skills.

Self-regulation and socially shared regulation are skills needed to adapt to the constantly changing learning and work contexts of the 21st century (Järvelä & Hadwin, 2013). When considering how to successfully facilitate and achieve active and engaging learning, it is clear that successful students regulate their own learning. Earlier research has shown that successful learners use a repertoire of strategies to guide and enhance their learning process – including cognitive, behavioural, and motivational strategies – toward completing academic tasks (Schunk & Zimmerman, 2008). Self-regulated and strategic learning involves experimenting with and learning about effective strategies for regulating (i.e., planning, setting goals, organizing, monitoring) aspects of their own, peers', and groups' shared learning process (Winne & Hadwin, 1998).

Today, regulating learning is rarely a solitary task. Pressure toward active learning and engagement in shared learning situations is increasing because of complex interactions in changing learning contexts (Järvelä, Järvenoja, & Veermans, 2008; Järvenoja & Järvelä, 2010; Näykki, Järvelä, Kirschner, & Järvenoja, 2014); for example, study groups, work teams, or social networks require increased collaborative competence (Scardamalia & Bereiter, 2006). Socially shared regulation occurs when groups regulate together as a collective, such as when they construct shared task perceptions or shared goals (Hadwin, Järvelä, & Miller, 2011). When groups co-construct plans or align monitoring perceptions to establish a shared evaluation of progress, they are engaged in shared regulation. Therefore,

socially shared regulation of learning refers to processes by which group members regulate their collective activity.

4 Pedagogical Designs for 21st Century Teacher Education

In this section, we will elaborate the core features of our pedagogical approach for teacher education. Promoting collaborative problem solving and strategic learning skills, especially socially shared regulation of learning, presumes situations where students face learning *challenges*. In order to be strategic, learners need to have an opportunity to activate their own problem exploration and participation (Malmberg, Järvenoja & Järvelä, 2013). This is also the case in the regulation of learning. Challenge situations stimulate students to regulate and change their strategic activity. Without challenges there is no need for the regulation of learning (Hadwin et al., 2011). There is also an emphasis in the framework of the socio-constructivist perspectives of computer-supported collaborative learning (Brown, Collins, & Duguid, 1989; Scardamalia & Bereiter, 2006) on the need for learners to be engaged in solving authentic, ill-structured, and *complex problems* for deep learning to take place. We know that this kind of work is not easy; furthermore, achieving learning with understanding and high-level collaboration is not self-evident, and this is especially true in minimally structured learning environments (Kirschner et al., 2006).

Inquiry-based instructional approaches are often referred to as learner-centred, which requires the learner to observe, generate questions, discover gaps in one's knowledge base, and study resources to try to overcome these gaps (Hmelo-Silver, Chinn, Chan, & O'Donnell, 2013). In order to change the student's passive role as a receiver, inquiry-based teaching comprises a whole spectrum of instructional techniques which offers a variety in the degree of use of inquiry practices, such as generating questions and giving and evaluating

explanations (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). In our approach, we will focus on the *process of inquiry from a pedagogical perspective*, and we treat inquiry as a method for structuring activities in the study contexts, especially focusing on inquiry-based instructional formats such as problem-, project-, and case-based learning approaches. All these instructional approaches *require student control*; the students take responsibility for their learning process (Dochy, Segers, Van den Bossche, & Gijbels, 2003; Mäkitalo-Siegl & Fischer, 2013; Savery, 2006) and *regulation of learning* (Hadwin et al., 2011). Students need to plan learning activities, monitor progress, and evaluate their progress on a regular basis, both individually and collaboratively, and these activities are closely related to strategic learning skills. Also, all inquiry-based instructions work *with meaningful tasks*, whether they are questions, problems, projects, or cases, and therefore activities are placed in a realistic context for students. Earlier studies have shown both positive and some mixed results when studying the effects of inquiry-based learning approaches (Gijbels et al., 2005; Hmelo, 2004; Kirschner et al., 2006).

In order to prepare pre-service teachers' 21st century skills (See Figure 1), we have defined a pedagogical model for the inquiry-based collaborative approaches. This involves four components to be taken into account in the pedagogical designs: (1) task types, (2) activities, (3) resources, and (3) levels. *Task types* are ill-structured, complex and challenging tasks that aim to foster problem solving competences and strategic learning skills. Typical task types are inquiry-, problem- and case-based tasks. The aim of the learning tasks is to trigger productive collaborative *activities* such as argumentation, explanation, negotiation and questioning in order to trigger learning mechanisms. Typical *resources* that students use in our pedagogical designs are technologies to mediate collaborative interactions (computers, tablet PCs, personal mobile devices, interactive whiteboards and tables, social media, wikis),

other materials, peer students and teacher. Students work and collaborate in multiple *levels* covering activities in individual, small-group, whole-class and community-levels.

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Furthermore, student collaboration will be supported by instructing and prompting collaborative problem solving (CPS) and socially shared regulation (SSRL) so that all participants may benefit from such an effort. With the aid of scripting (Kollar, Fischer, & Hesse 2006), participants can engage in cognitive (questioning, explaining), meta-cognitive (monitoring, regulating, and formulating arguments and counter-arguments), and social activities (taking turns, listening, playing specific roles). Specific instructions and prompts activate problem solving related regulation and focus on other group members' thought and activities. Therefore, a variety of instructions provide different levels of structure.

The particular features to be built into the designs aim to facilitate the core principles of CPS and SSRL (see Table 1):

- CPS = effective engagement in a process of solving a common challenge or problem with others, including the contribution and exchange of ideas, knowledge, or resources, and sharing understanding and effort required to achieve a shared goal.
- SSRL= involves the construction and maintenance of interdependent or collectively shared regulatory processes, beliefs, and knowledge (e.g., strategies, monitoring, evaluation, goal setting, motivation, metacognitive decision making) orchestrated in the service of a co-constructed or shared outcome.

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5 Concrete Applications of Training Pre-Service Teachers to Develop' 21st Century Skills

The aim of the following cases is to demonstrate our approaches presented above to enhancing the different areas of 21st century skills. On the basis of our earlier studies, we will provide examples of the methods for supporting collaborative problem solving, strategic learning skills, and the use of ICT for learning, which will provide grounding for our ongoing research.

5.1 Case "Enhancing and Assessing Collaborative Problem Solving"

The ATC21s project explored new ways of assessing 21st century skills and linking them to teaching interventions aimed at deepening learning and enabling students to develop higher levels of skill (Griffin, Care, & McGaw, 2012). A computer-based assessment portal including tasks to assess collaborative problem solving (CPS) was developed at the Assessment Research Centre in the University of Melbourne. In Finland, a thousand (N = 1000) 11–15-year-old students from ten comprehensive schools participated in the ATC21s study, in which they solved *collaborative problem solving tasks* in pairs through the Internet in *a cloud-based system of learning and assessment tasks* (Authors, in press). The tasks were *complex sudo game-like tasks* largely in the science and math domains and were related both to curriculum contents and to generic skills (e.g., understanding rules). They were designed in a way that required students to bring different resources together and form a *positive interdependency* with each other. The students logged into common tasks as players A and B, but they had different functions and tools in use. The assignment was to collaborate via chat box to create a common *task understanding* of the problem and to solve it together. The

students needed to *regulate* their work both toward solving the task and with regards to their partners' actions to reach the common goal.

The cloud-based system was used to *assess and measure current skill levels* against learning progressions. Behind-the-scenes data analysis linked data on students' work on the tasks to reporting modules. The aim of the reporting modules was to show skill assessments at the individual, class, and system levels, and in this way guide teaching in these skills. Each skill was scaled based on the actions taken and collected as process data, and online chat/discussions that took place during performance of the task. The scoring itself took into consideration student actions as they moved through the tasks – exploration of the task environment by selecting or clicking on options or artefacts – in such a way that the students' thinking process was demonstrated and their skill level was made explicit. The analyses of the log-file data from task completions were based on automated scoring, which was based on the Rasch model.

In our current project, we will apply the cloud-based system in the context of teacher education, in which the assessment session is followed by the debriefing part of the students' scores, and *evaluation and monitoring* of their skills and performance during the tasks. Debriefing takes places in small groups and it is also possible to get individual feedback. Additionally, students participate in a course that consists of professional development material of the ATC21s program regarding the collaborative problem solving skills and the assessment features behind these skills. During the course the students will accomplish the following: 1) explore the conceptual and theoretical frameworks used in defining collaborative problem solving; 2) explore the developmental hierarchies of collaborative problem solving; and 3) identify the rubrics associated with collaborative problem solving.

5.2 Case "Multimedia as a Learning Project in Teacher Education"

First-year Finnish pre-service teachers (N = 103) participated in a "Multimedia as a learning project" course that lasted for two months. The students worked in groups of three to four members (32 groups) during nine sessions with a face-to-face and an online phase. The Virtual Collaborative Research Institute (VCRI) (http://edugate.fss.uu.nl/~crocicl/vcri_eng.html) is an online tool that promotes collaborative work (Janssen, Erkens, & Kirschner, 2011).

During the nine collaborative face-to-face learning sessions the students' task assignment was to *plan, design, and develop* one imaginary digital story with iPads. The purpose of the assignment was to learn and practice how to use iPads in their future work as a teacher. During each of the nine online learning sessions the students were asked to write a short essay on different topics. The purpose of this assignment was to make a *pedagogically relevant plan for the use of iPads when teaching*, for example, history, arts, or science. Altogether, each student group wrote nine essays. The online tasks were considered to be relevant for the students for their future work as a teacher because they *encouraged student teachers to think technological advances in their teaching*. In each collaborative online learning session the students used the VCRI environment, which was tailored to prompt socially shared regulation of learning, such as shared *goal-setting and planning, regulating emotions and motivation as well as monitoring and evaluating collaborative activities* (See Authors, 2014). During the last collaborative online learning session the students were asked to write an essay considering "threads and possibilities of technology in teaching and learning." The purpose of the final essay was to collect and summarize the constructed core ideas which the students had developed together. Finally, students presented their essays when the class met face to face.

5.3 Case "Science in Teacher Education"

The "Science in teacher education" case contained a compulsory course of physics and chemistry. The participants included 110 first-year pre-service teachers. The course consisted of 20 hours of lectures and 26 hours of laboratory work in small groups (three to five pre-service teachers) with 20 to 22 pre-service teachers in one laboratory class. The intervention focused on the laboratory working part during which the pre-service teachers conducted experiments focusing on topics in physics and chemistry and engaging in *inquiry-based learning*. Students worked with open-ended learning assignments and were encouraged to *explore and analyse problems*, define the problem space, bring up their earlier ideas, formulate hypotheses, and design and conduct experiments to test their hypotheses. Based on these experiments, they produced learning materials that align with the Finnish elementary school curriculum. Afterwards, the pre-service teachers were also encouraged to *collaboratively monitor and evaluate* their learning.

In order to support pre-service teachers' collaboration and problem solving processes, the learning environment contained several ICT applications. In addition to laboratory equipment, the learning environment contained easily available everyday ICT applications like smart phones with cameras, laptop computers and social software applications (wiki-environments, YouTube, Facebook). The ICT applications were used for various purposes, and the applications provided concrete support for conducting experiments. With cameras and YouTube the pre-service teachers were able to better capture and highlight essential phenomena and results of their research projects. In addition, with different social software applications the problem-solving process could be structured by the teacher; furthermore, the whole process was captured in these environments (for example, wiki-environments and YouTube). These social software applications served as a cloud for sharing and elaborated

their pre-conceptions and findings from the experiments for capturing the learning process. The ICT applications were also meant to serve as a shared reference point for launching conversation about the topic in small groups.

5.4 Summary of Case Examples

The case examples varied in terms of the type of task, level of collaboration, time-scale, technology, and the particular ways in which these case examples aimed to enhance CPS and SSRL (see Table 2).

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The common goal in all the case examples was to support the pre-service teachers' collaboration, problem solving and regulation processes as well as to provide pre-service teachers with inspiring and pedagogically justified examples of ways to use ICT for learning. According to Lei (2009), today's pre-service teachers have difficulties with using ICT for teaching and learning based on their weak experiences of learning with ICT. Our cases were designed to meet this challenge by providing pre-service teachers with concrete experiences of learning with ICT while at the same time enhancing the 21st century skills.

6 Conclusions

Teacher education has been challenged by the need to enhance the new teachers' ability to implement new pedagogical approaches and take advantage of ICT for teaching and learning. Teacher education also constantly faces the challenges of disconnecting theory and practice

(Korthagen & Kessels, 1999; Zeichner, 2010). Overall, the current way of working in teacher education does not match well enough the needs of 21st century learning environments, such as inquiry-based learning approaches that focus upon collaboration and social forms of learning, as well as the use of ICT (social media, wikis, blogs, mobile technology, CSCL) in teaching and learning. These, in turn, require students to have skills related to collaboration, the strategic regulation of learning, and the ability to use ICT in a rapidly changing learning society. In our approach, pre-service teachers are educated in a way they are supposed to teach their future students. In this paper we have described some of the recent policy frameworks for 21st century skills, and focused more thoroughly on the particular skill areas (collaborative problem solving and strategic learning skills) that have formed the basis for our pedagogical framework in the teacher education context.

Many countries have started reforms in the mission statements of their educational systems as a result of international comparisons (e.g., PISA). There is a general notion that education and work have changed, and hence, the challenge is to educate next generation problem solvers and communicators. As one of the main justifications for education is to prepare our students to enter the world equipped to cope with challenging and complex problems, it is also important that our educational systems incorporate the 21st century skills into curricula. It is typical that the facilitation of these skills is embedded into innovative projects and development initiatives, but the challenge is to scale them up more broadly. For example, how do we scale up inquiry-based, collaborative approaches into policy and implement them on a systemic level?

Sleeter (2014) has criticized teacher education research of not providing systematic evidence of the classroom impact of teacher education initiatives. Due to the lack of evidence, teacher education research is not capable of informing policy well enough. There is also a lack of large-scale and mixed-methods studies in teacher education research. For

example, there has been no systematic and long-term research on the impact of different pedagogical approaches toward the 21st century skills and attitudes in the context of teacher education. In addressing the complexities of learning to teach in a powerful way, it is important to provide empirical evidence of the impact of pedagogical approaches on progression of students' skills that are aimed to be facilitated.

In this article, we have presented a theory-based pedagogical framework for the 21st century learning practices in teacher education that will provide grounding for the empirical phase of our ongoing study. In the next phase of our research, we will produce empirically tested knowledge on the effects of our framework with the aid of a mixed method research approach (Creswell & Plano Clark, 2011). The rationale for the mixed method approach is twofold. Firstly, our longitudinal, four-year follow-up research with repeated measures will provide a general understanding about the growth patterns in teacher students' core skill areas: strategic learning skills, collaborative problem solving skills and skills in integrating pedagogy and technology. Secondly, in order to understand in depth what the reasons for possible differences in growth patterns are, under what circumstances guided inquiry-based approaches work best, and for what kinds of outcomes they are effective, we will also conduct theory-driven interventions and process-oriented research related to them (Barab & Squire, 2004).

The basic principles of our interventions for inquiry-based collaborative learning with the particular support for collaborative problem solving and socially shared regulation have been described earlier in this article. As a long-term effect, this research project will provide knowledge on how to develop current teacher education to be more productive and ready to react to challenges of our learning society and the future of schooling.

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Appendix 1. Comparison of 21st Century Skills Frameworks

Assessment and Teaching for 21st Century Skills	**A Partnership for 21st Century Skills P21Skills**	**OECD DeSeCo**	**European Union Key Competences for Life Long Learning 2008**
Ways of Thinking			
Creativity and innovation	Creativity and innovation	Information as a product:	Learning to learn
Critical thinking, problem solving, decision making	Critical thinking, problem solving	Restructuring and modelling of information and the development of one's own ideas (knowledge)	
Learning to learn, meta cognition			
Ways of working			
Communication	Communication	Effective communication:	Communication in the mother tongue
Collaboration (teamwork)	Collaboration	Collaboration and virtual interaction	Communication in the foreign languages
Tools for working			
Information literacy	Information literacy, media literacy	Information as a source:	Mathematical competence and basic competences in science and technology
ICT literacy	ICT literacy	Searching, evaluating, and organizing information	Digital competence
Living in the world			
Global and local citizenship	Flexibility and adaptability	Ethics and social impact dimension of communication:	Cultural awareness and expression
Life and career	Initiative and self-direction	Social responsibility	Social and civic competences
Cultural awareness and social responsibility	Social and cross-cultural skills	Social impact	Sense of initiative and entrepreneurship
	Productivity and accountability		
	Leadership and responsibility		

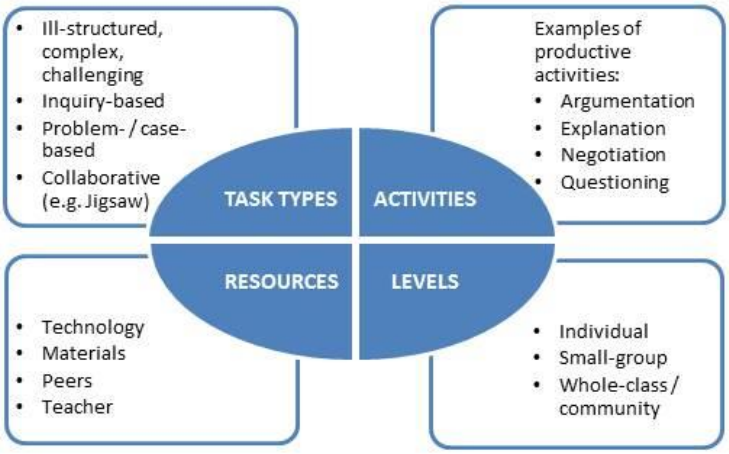

Figure 1. Theory-Based Pedagogical Model

Table 1. Design Principles for Supporting Socially Shared Regulation of Collaborative Problem Solving

CPS	SSRL	Operationalization of theoretical principles into practice
Problem exploration and analysis Task regulation Perspective-taking Constructive conflicts	Task understanding Goal setting Activating learning strategies Regulating emotions and motivation Monitoring and evaluating	➢ Negotiating task constructs and task understanding ➢ Negotiating interests, involvement, and goals ➢ Negotiating how to proceed with the task as a group ➢ Planning tasks and sub-tasks ➢ Collecting information and managing resources ➢ Exploring alternative solutions ➢ Coordinating and monitoring understanding and proceeding against group's standards
Reactive, process-oriented monitoring and support (e.g., prompts, scaffolds)		

Table 2. Design Principles Applied in Our Earlier Case Examples in Teacher Education

	ATC21s	**Multimedia**	**Science**
Type of task	collaborative solving of puzzles	collaborative creation of digital stories	inquiry-based science learning
Level of collaboration	dyads / pairs	small-groups	small-group and whole-class activities
Time-scale	1–2 hour sessions	series of working sessions	series of working sessions
Technology applied	synchronous collaboration, game-like puzzles, chat	iPads, VCR environment	smart phones, iPads, social software
CPS principles	problem exploration and analysis, task regulation, perspective-taking, constructive conflicts	task regulation, perspective-taking	problem exploration and analysis
SSRL principles	task understanding, monitoring and evaluating	goal setting, activating learning strategies, regulating emotions and motivation, monitoring and evaluating	productive learning strategies, monitoring and evaluating