



Contents lists available at ScienceDirect

## Computers in Human Behavior

journal homepage: <http://www.elsevier.com/locate/comphumbeh>

Full length article

## How pre-service teachers perceive their 21st-century skills and dispositions: A longitudinal perspective

Teemu Valtonen<sup>a,\*</sup>, Nhi Hoang<sup>a</sup>, Erkkö Sointu<sup>a</sup>, Piia Näykki<sup>b</sup>, Anne Virtanen<sup>c</sup>,  
Johanna Pöysä-Tarhonen<sup>c</sup>, Päivi Häkkinen<sup>c</sup>, Sanna Järvelä<sup>b</sup>, Kati Mäkitalo<sup>b</sup>, Jari Kukkonen<sup>a</sup>

<sup>a</sup> University of Eastern Finland, Faculty of Philosophy, P.O.BOX 111, 80101, Joensuu, Finland

<sup>b</sup> University of Oulu, Department of Educational Sciences and Teacher Education Learning and Educational Technology Research Unit (LET), P.O.BOX 2000, Oulu, Finland

<sup>c</sup> University of Jyväskylä, Finnish Institute for Educational Research, P.O. Box 35, FI, 40014, Jyväskylä, Finland



## ARTICLE INFO

## Keywords:

21st-century skill  
Pre-service teacher  
Longitudinal study  
Latent growth curve modeling

## ABSTRACT

Research-based discussions about 21st-century skills are currently needed; 21st-century skills refer to skills that today's students are expected to possess for successful future careers. The ways students perceive these skills or what kind of dispositions they have in this regard are significant. This paper provides an overview of the development of pre-service teachers' perceived 21st-century skills and dispositions. The quantitative data was collected in three phases during 2014, 2015, and 2016 at three Finnish universities. The number of respondents at each measurement point varied from 209 to 267. Data were analysed using latent growth curve modeling. The study focuses on students' perceptions of three areas related to 21st-century skills: learning skills, collaboration dispositions, and skills to use ICT. The results show that the three areas evolved in different ways. Learning skills and collaboration dispositions show up as yearly assessments that remain at the same level, with small differences among respondents, unlike skills to use ICT with bigger yearly changes. The measured areas also appear as separate entities throughout the bachelor's studies, with small or non-significant correlations. These results reveal important new perspectives on how pre-service teachers perceive 21st-century skills and how perceptions evolve during teacher education.

## 1. Introduction

Today's students are expected to have various skills to be successful in their future working life. These so-called 21st-century skills have been defined by different international organizations and projects, such as the Assessment and Teaching of 21st-Century Skills project, the Partnership for 21st-Century Skills, the OECD's Definition and Selection of Competences, and the European Union's Key Competences for Lifelong Learning (Ananiadou & Claro, 2009; Binkley et al., 2012; Gordon et al., 2009; P21Skills, 2013). According to Voogt and Roblin (2012), what is common for these definitions is the emphasis on collaboration, communication, ICT literacy, creativity, critical thinking, problem solving, and social and cultural competencies (cf. Voogt et al., 2013).

Compared to traditional school subjects, such as biology, languages, history, and mathematics, 21st-century skills are not conflicting; rather,

they are best learnt together as content-specific skills and knowledge (e.g., Rotherham & Willingham, 2009; Silva, 2009). For 21st-century skills, the emphasis in learning is toward the readiness to use knowledge for different purposes instead of memorising facts (Silva, 2009). The expectation of 21st-century skill development poses demands for teachers. According to Voogt et al. (2013), p. 21st-century teachers must be competent in their learning and working skills; they need abilities and pedagogical practices that support their students' skill development. According to Fraillon (2014), teachers need to be able to integrate the training of 21st-century skills into pedagogical approaches. Again, this poses expectations for teacher education. Teacher training needs to provide new teachers with the competence to use pedagogical practices aligning with 21st-century skills. According to Häkkinen et al. (2017), teacher education can be a powerful channel to trigger longer-term change and support the integration of 21st-century skills within

\* Corresponding author. University of Eastern Finland, Faculty of Philosophy, P.O.BOX 111, 80101, Joensuu, Finland.

E-mail addresses: [teemu.valtonen@uef.fi](mailto:teemu.valtonen@uef.fi) (T. Valtonen), [nhi.hoang@uef.fi](mailto:nhi.hoang@uef.fi) (N. Hoang), [erkko.sointu@uef.fi](mailto:erkko.sointu@uef.fi) (E. Sointu), [piia.naykki@oulu.fi](mailto:piia.naykki@oulu.fi) (P. Näykki), [anne.virtanen@juu.fi](mailto:anne.virtanen@juu.fi) (A. Virtanen), [johanna.poyasa-tarhonen@juu.fi](mailto:johanna.poyasa-tarhonen@juu.fi) (J. Pöysä-Tarhonen), [paivi.m.hakkinen@juu.fi](mailto:paivi.m.hakkinen@juu.fi) (P. Häkkinen), [sanna.jarvela@oulu.fi](mailto:sanna.jarvela@oulu.fi) (S. Järvelä), [kati.makitalo@oulu.fi](mailto:kati.makitalo@oulu.fi) (K. Mäkitalo), [jari.kukkonen@uef.fi](mailto:jari.kukkonen@uef.fi) (J. Kukkonen).

<https://doi.org/10.1016/j.chb.2020.106643>

Received 28 May 2020; Received in revised form 15 November 2020; Accepted 21 November 2020

Available online 1 December 2020

0747-5632/© 2020 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

everyday school practices.

According to [Silva \(2009\)](#), p. 21st-century skills are nothing new, but rather, newly important. According to [Voogt & Roblin, 2012](#), p. 21st-century skills need to be defined in terms of knowledge, skills, attitudes, values, and ethics. Various articles provide lists of skills included in 21st-century skill framework ([Valtonen et al., 2017](#)). According to [Van Laar et al. \(2017\)](#), the list of 21st-century skills is extensive, making it challenging to design a test that would cover all the areas. Within this study, we investigate the development of pre-service teachers' perceived 21st-century skills and dispositions. For this purpose, 21st-century skills and dispositions were operationalized using theoretical frameworks with long research traditions and validated instruments. This research targets 21st-century skills from the perspectives of three core areas: learning skills ([Pintrich, 2000](#); [Weinstein et al., 2000](#)), collaboration dispositions ([Wang et al., 2009](#)) and skills to use ICT ([Mishra & Koehler, 2006](#); [Teo & Van Schaik, 2012](#)). These areas are selected for operationalising 21st-century learning based on previous descriptions of 21st-century skills ([Van Laa et al., 2017](#); [Voogt & Roblin, 2012](#)) and because of their central role within today's and the future's working life. To cope with an evolving society and work life, people need to constantly adapt and learn new skills and competencies. This highlights the importance of abilities for self-regulated and collaborative learning ([Ericsson, 2009](#); [Scardamalia et al., 2012](#)). In addition, careers now and in the future demand collaboration between different disciplines, indicating a need to work in teams with people of varied backgrounds and expertise ([Graesser et al., 2017](#); [Griffin et al., 2012](#)). In the same vein, ICT skills are needed for supporting other 21st-century skills and are important skills themselves ([Voogt & Roblin, 2012](#)).

Teacher education needs to provide teachers with opportunities to develop their own 21st-century skills and abilities to take these skills into their future classrooms ([Voogt & Roblin, 2012](#)). Pre-service teachers need to be provided constant support for the development of their 21st-century skills to provide them with confidence to integrate 21st-century skills into their teaching ([Urbani et al., 2017](#)). These expectations make pre-service teachers' developing 21st-century skills an important research topic. Thus far, studies have mainly been cross-sectional for describing pre-service teachers' 21st-century skill and intervention studies for supporting the development of 21st-century skills with different courses and activities ([Aslan, 2015](#); [Bedir, 2019](#); [Nissim et al., 2016](#); [Urbani et al., 2017](#); [Valtonen et al., 2017](#)). What is missing are studies focusing on the development of pre-service teachers' 21st-century skills over time. This study provides a longitudinal perspective on pre-service teachers' perceptions of their 21st-century skills and dispositions, as well as how perceptions evolve during bachelor's studies within Finnish teacher education.

## 2. Theoretical Framework

The following chapter provides an overview of the three core areas of this study: learning skills, collaboration dispositions, and skills to use ICT. The aim is to outline the theoretical frameworks used for operationalising 21st-century skills and dispositions. The aim is to highlight the importance of these areas within a 21st-century skill framework and within teacher education.

### 2.1. Learning skills

The central theoretical orientation that explores learning skills is the theory of self-regulated learning (SRL). In this study, SRL is viewed through pre-service teachers' perceptions of their cognitive and metacognitive learning strategies (i.e., critical thinking, elaboration, and metacognitive SRL; [Pintrich, 2000](#)). Self-regulated learners are active learners: They set learning goals, monitor their progress toward those goals, and make changes when needed, either by reformulating the goals or by selecting different learning strategies ([Pintrich, 2000](#); [Schunk & Greene, 2017](#); [Zimmerman, 2000](#)).

In general, definitions of learning strategies can vary depending on whether a strategy is viewed as a subcomponent of SRL or whether SRL is viewed as a part of strategic learning ([Weinstein et al., 2000](#); [Winne & Perry, 2000](#)). In this study, learning strategy use is viewed as a part of SRL; the actual strategy use occurs because of comparisons of current learning with a desired learning outcome ([Pintrich, 2000](#); [Winne & Hadwin, 1998](#)). Prior research has compared the function and meaning of types of learning strategies. In general, cognitive strategies include the use of basic and complex strategies that facilitate information processing for enhancing understanding and meaningful encoding into memory ([Weinstein et al., 2011](#)). However, metacognitive learning strategies involve planning, executing, and monitoring learning tasks by attending to and evaluating the degree to which new information is being understood, integrated, and retained ([Flavell, 1979](#)). In all, decades of studies, especially among higher education students, including pre-service teachers ([Dignath, 2017](#)), show unquestionable evidence that SRL is effective for improving student achievement ([Zimmerman & Schunk, 2011](#)). Many prior studies have reported different relationships between strategy use and academic achievement, depending on whether the strategies are metacognitive or cognitive ([Proctor et al., 2006](#)). A metacognitive approach to learning has been associated with the deeper processing of information ([Evans et al., 2003](#)) and may be particularly important to academic success.

However, empirical evidence indicates that students often do not use strategies in a high-quality way ([Glogger et al., 2012](#); [Simpson et al., 1994](#)). Decades ago, research demonstrated a poor repertoire of learning strategies can lead to academic failure as early as the first year of higher education ([Tait & Entwistle, 1996](#)). Research has also shown the use of learning strategies can be taught and scaffolded ([Perry, 1998](#); [Zimmerman, 2000](#)) and the most successful results have been gained by training programmes connected to authentic learning tasks and the larger framework of SRL ([Dignath, 2017](#)). Thus, exploring pre-service teachers' learning skills and use of cognitive and metacognitive learning strategies during their first years of teacher education gives information about what kind of learners they are, how their skills develop during teacher education, and what kind of support they may need in their learning skill development. This is important for the sake of their learning and development, but it is particularly important for them as future teachers, to model and support well-functioning SRL skills among their prospective students.

### 2.2. Collaboration dispositions

In educational policy discussions, collaboration (along with individual learning skills) is recognized as a critical skill to be acquired by 21st-century learners ([Gauvain, 2018](#); [Graesser et al., 2017](#); Organisation for Economic Co-operation and Development [OECD], 2017). In today's world, many problems, be they economic, environmental, health, or social, require teamwork and individuals with adequate social skills to succeed. Based on earlier research, participation in collaborative learning activities may enhance individual learning ([O'Donnell & Hmelo-Silver, 2013](#)), not only in terms of gaining content knowledge but also by achieving collaboration skills that resonate well with the skills needed in modern team-based organizations ([Gauvain, 2018](#)). Through participation in collaborative learning activities, individuals can observe the mechanisms that underlie social processes and see the consequences of joint effort on targets set for learning.

Although collaboration skills can be taught and trained (e.g., [Littleton & Mercer, 2013](#)), an affirmative disposition toward collaboration also plays a central role in achieving these skills, since the willingness to contribute to joint work is considered important ([Fransen et al., 2013](#)). That is, even though the skills and knowledge of how to collaborate may exist, actual dispositions may ultimately determine how people act in practice ([Schussler, 2006](#); [Tiilikainen et al., 2019](#)). Even though multiple definitions exist, in this study, *disposition* refers to relatively stable attitudes or habits (e.g., [Schussler, 2006](#)), reflecting an "actual tendency to

act and think in specific way” (Tiilikainen et al., 2019, p. 126). In terms of teacher dispositions (Toom, 2017), they are related, for example, to learning theories that guide the instructional choices of the teachers (Altan et al., 2017). Therefore, recognizing dispositions in teachers’ thought processes is essential, as well as pre-service teachers, for them to be able to support their pupils.

In this study, we focus on pre-service teachers’ dispositions, studied as individuals’ general attitudes toward teamwork, collaboration, and collaborative problem solving (Wang et al., 2009; see also OECD, 2017). This approach covers collaboration dispositions toward various dimensions of teamwork, including a cooperative mindset, team leadership, and negotiation. A *cooperative mindset* refers to a general attitude toward working as a team and in collaboration, for example, how effective or preferable this mode of work was perceived to be. Team leadership, in turn, focuses on dispositions towards guiding other team members and taking responsibility for a group product. Negotiation disposition can be seen as a central element of teamwork that requires individuals to negotiate, consider others’ perspectives, and adjust their actions according to the team. In general, collaboration dispositions are expected to be associated with how students succeed in collaborative activities in general (OECD, 2017) but also with their personal development in teaching practices during their studies (Buzza & Allinotte, 2013; Gordon et al., 2007).

### 2.3. Skills to use ICT in education

Besides learning skills and collaborative dispositions, this study focuses on pre-service teachers’ perceptions of their skills to use ICT in education. Aligning with Voogt & Roblin, 2012 and Van Laar et al. (2017), ICT skills are in key position within 21st-century skills. ICT is seen both as a target for learning itself and as a tool for supporting other 21st-century skills by enhancing opportunities for learning, collaboration, problem solving, and creativity (Voogt & Roblin, 2012). To study pre-service teachers’ skills to use ICT in education, the study implements two actively used theoretical frameworks. The first theoretical framework is technological pedagogical content knowledge (TPACK) by Mishra and Koehler (2006), and the second framework is the theory of planned behavior (TPB) by Ajzen (1991).

TPACK is a theoretical framework for studying pre-service and in-service teacher knowledge related to the use of ICT in education (Mishra & Koehler, 2006). It is based on three foundational elements: technological knowledge, pedagogical knowledge, and content knowledge. These elements are combined in different ways: *Technological pedagogical knowledge* (TPK) refers to knowledge that takes advantage of ICT for supporting different pedagogical practices (Mishra & Koehler, 2006). *Pedagogical content knowledge* (PCK) refers to the combination of content knowledge and pedagogical knowledge and, as suggested by Shulman (1987, p. 8), is a “special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding.” *Technological content knowledge* (TCK) refers to knowledge of how ICT is used within different disciplines, such as mathematics, arts, or history (Mishra & Koehler, 2006). Finally, TPACK combines these areas as “an understanding that emerges from interactions among content, pedagogy, and technology knowledge ... knowledge underlying truly meaningful and deeply skilled teaching with technology” (Koehler et al., 2013, p. 66).

The second theoretical framework used is the Theory of Planned Behavior (TPB) by Ajzen (1991). The TPB provides a model of factors affecting certain behaviors, in this case the use of ICT in education. Aligning with the TPB, a certain behavior is affected by intentions to behave. Again, intentions are affected by four areas: 1) attitudes towards the behavior, that is, how one values the behavior, 2) subjective norms, that is, how important others value the behavior, 3) perceived behavioral control, that is, does one have the facilities and resources to behave, in this case, implement ICT in education, and how one sees his/her skills to perform the planned behavior, and 4) self-efficacy

toward the behavior (Ajzen, 2002).

The TPACK and TPB frameworks have been actively used within teacher education contexts, providing good working tools for studying pre-service teachers’ skills to integrate ICT in education (Harris et al., 2017; Teo & Lee, 2010; Teo & Van Schaik, 2012). In this study, the skills to use ICT in education are studied from two perspectives: TPK from the TPACK framework and self-efficacy from the TPB framework. These areas are used because they are general level areas. These areas assess pre-service teachers’ perceptions of their skills to use ICT in education without any specific content topics or technology-specific areas.

Overall, these three areas of 21st-century skills have long-researched traditions with validated instruments. This study consists of three measurements conducted during the first three years of teacher education. The aim is to gain perspective for the development and changes within 21st-century skills without specific interventions or a course for fostering 21st-century skills. Teacher education needs to provide models of the simultaneous integration of 21st-century skills (Urbani et al., 2017). Aligning with Koehler et al., 2013, the relationship between pedagogical knowledge and technological knowledge needs to be transactional. Voogt & Roblin, 2012 argue that ICT skills need to be embedded with other 21st-century skills. This poses questions about the relationship of 21st-century skills, whether the areas are perceived as separate entities or as a more cohesive entity. This study provides insights into how these relationships evolve during teacher education.

## 3. Methods

The aim of this study is to provide longitudinal perspectives on possible changes in pre-service teachers’ perceptions of their 21st-century skills and dispositions during their bachelor’s degree studies (i.e., the first three years) of their teacher education. The research questions are as follows:

1. How do pre-service teachers perceive the three areas of 21st-century skills evolving during the first three years of teacher education?
2. How does the relationship between the measured areas evolve during the first three years in teacher education?

### 3.1. Participants

The target group consisted of pre-service teachers from three Finnish universities. The selected cohorts started their studies during Autumn 2014. Data collection was conducted in three phases, during 2014, 2015, and 2016, in teacher education courses. Data was collected as part of the normal teacher education courses using online questionnaires or paper questionnaires. The total number of respondents at each measurement point varied from 209 to 267 (Table 1). The changes in response rate were due to voluntarily participation in the study and

**Table 1**  
Target group of the study.

Description	Three years’ cohort measures		
	2014 (T1)	2015 (T2)	2016 (T3)
University 1	81	78	61
University 2	53	46	56
University 3	134	102	92
TOTAL	267	228	209
Gender distribution	76% female, 24% male	75% female, 25% male	79% female, 21% male
Mean Age (SD)	21.68 (3.57)	22.49 (3.35)	23.17 (2.83)

Note: 365 new pre-service teachers were accepted in 2014, T1 first measurement point, T2 second measurement point, T3 third measurement point, SD Standard Deviation.

because not all the expected respondents participated in the courses where data was collected. The dropouts were random, the drop-out rates were 14.6% for time 2 and 21.7% for time 3. These drop-out rates are acceptable for the methods used (see. Gustavson et al., 2012). The method for handling the missing data was Full Information Maximum Likelihood (FIML).

### 3.2. Context of the study

Teacher education in Finland consists of two degrees, the bachelor of arts (education) degree (180 ECTS) and the master of arts (education) degree (120 ECTS). The bachelor of arts (education) degree consists of the first three years of teacher education. In Table 2, there is a list of study units in the participating universities, the courses provided for the target group pre-service teachers. There are differences between the universities in the names of the units. Moreover, the extent of the units slightly varies (i.e., the number of credit points).

Communication studies and orientation focus on communication, language skills, and university-level studies. Courses within this unit also contained ICT in education courses. In addition, there were courses dealing with research methods in educational science. The first practice period was also within this unit. Multi-disciplinary studies contained courses for the different discipline areas taught in elementary schools (grades 1 to 6): arts, music, history, mathematics, geography, Finnish, literature, etc. This unit was compulsory to gain qualification to teach pupils in grades 1 to 6. Bachelor’s degree studies also contained minor subject studies based on pre-service teachers’ personal interests, providing advanced-level studies in areas like arts, special education, and multicultural studies.

Teaching and learning methods within Finnish teacher education varied from large auditorium lectures to methods based on pre-service teachers’ collaborative work in small groups. Studies also utilized self-study courses and book exams, portfolio assignments, laboratories, and demonstrations. Courses varied from face-to-face to more blended courses and online courses. The target groups consist of pre-service teachers who will be teaching grades 1 to 6 following the Finnish National Core Curriculum. The curriculum contains seven so-called transversal skills that need to be embedded in all teaching disciplines (Finnish National Board of Education, 2014). These skills are close to 21st-century skills, including themes such as thinking and learning skills, learning collaboratively, critical thinking, and ICT skills. Within the curriculum, pupils are seen as active learners, and collaborative learning activities and the pedagogically sound use of ICT as part of learning environments are emphasized. Teacher education aligns with these aims (i.e., the contents and teaching methods used are designed to provide teachers with abilities to meet the expectations of the curriculum).

### 3.3. Measures

The learning skills, collaboration dispositions, and skills to use ICT in education were measured using the instruments in Table 3. Learning skills were measured using the elements from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1993). The MSLQ is an 81-item self-report instrument consisting of nine learning strategy subscales and six motivation scales, using a scale from one to seven (1 =

**Table 2**  
Study units within Finnish teacher education.

Study units	University 1	University 2	University 3
Communication studies and orientation	15 CP	21 CP	20 CP
Basic studies of education	25 CP	25 CP	25 CP
Intermediate studies of education	45 CP	40 CP	38 CP
Multi-disciplinary studies	65 CP	60 CP	60 CP
Minor subject studies	30 CP	34 CP	37 CP
TOTAL	180 CP	180 CP	180 CP

**Table 3**  
Number of items, Cronbach’s alpha ( $\alpha$ ), and example items.

	Items	$\alpha$ T1	$\alpha$ T2	$\alpha$ T3	Example item
ELA	4	.74	.79	.80	“When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.” “I try to relate ideas in this subject to those in other courses whenever possible.”
CRI	5	.76	.76	.77	“I often find myself questioning things I hear or read in this course to decide if I find them convincing.” “I treat the course material as a starting point and try to develop my own ideas about it.”
SRL	9	.74	.76	.77	“When reading for this course, I make up questions to help focus my reading.” “When I study for this class, I set goals for myself in order to direct my activities in each study period.”
TPK	6	.95	.93	.94	“I know how to use ICT in teaching as a tool for students’ creative thinking.” “I know how to use ICT in teaching as a tool for sharing ideas and thinking together.”
SE ICT	3	.87	.90	.92	“Teaching with ICT is easy for me.” “I am very skilled in using ICT for different purposes.”
NEGO	6	.73	.71	.84	“I enjoy seeing my classmates be successful.” “I am flexible when working with a team.”
COOP	4	.75	.74	.74	“I prefer working as part of a team to working alone.” “I find that teams make better decisions than individuals.”
LEAD	6	.74	.75	.79	“I like to be in charge of groups or projects.” “I convince others to see things my way.”

ELA elaboration, CRI critical thinking, SRL self-regulation, TPK technological pedagogical knowledge, SE ICT self-efficacy ICT, NEGO negotiation, COOP cooperative mindset, LEAD team leadership.

not at all true of me; 7 = very true of me). This study focused on the learning strategies of *elaboration* (ELA), *critical thinking* (CRI), and *self-regulation* (SRL). Collaboration dispositions were measured using the 20-item self-report instrument designed by Wang et al. (2009) using a scale from one to seven (1 = not at all true of me; 7 = very true of me). Measured areas were *negotiation* (NEGO), *cooperative mindset* (COOP), and *team leadership* (LEAD). Skills to use ICT in education were measured using parts of the TPACK21 instrument developed by Valtonen et al. (2017) and parts of the TPB instrument used in the study by Valtonen et al. (2015), both using a scale from one to six (1 = strongly disagree; 6 = strongly agree). The measured areas were *technological pedagogical knowledge* (TPK) and *self-efficacy ICT* (SE ICT). The internal consistency of each scale was good; all  $\alpha$  values were adequate at above 0.70 (e.g., Metsämuuronen, 2003). Cronbach’s  $\alpha$  values and example items are listed in Table 3. For all scale variables, the sum averages were calculated.

### 3.4. Analysis of the data

For the first research question, to study the development of pre-service teachers’ perceptions of their 21st-century skill areas, latent growth curve modeling (LGCM) was applied using Mplus 7.4. The development of each 21st-century skill was investigated separately. Eight LGCM models were fit using five indices: (a) the chi-square goodness of a fit test, (b) CFI (Bentler, 1990), (c) the TLI (Tucker & Lewis, 1973), (d) SRMR (Bentler, 1995), and (e) RMSEA (Steiger, 1990). According to Hu and Bentler (1999), values less than 0.08 for RMSEA and SRMR and bigger than 0.90 for CFI and TLI were considered good fits for an LGCM model. For the second research question, to study the relationship between 21st-century skill areas, the correlation between 21st-century skill areas, learning skills, collaboration dispositions, and ICT skills were studied.

#### 4. Results

The LGCM models showed good fit, with the indices of most models (except Lead) above 0.95 for CFI and TLI and lower than 0.08 for RMSEA and SRMR (see Table 4). Even though the model fit indices of team leadership were not as good as other models, they still showed acceptable fit: CFI = 0.981, TLI = 0.943, RMSEA = 0.10, and SRMR = 0.043.

The results of the LGCM show that changes in critical thinking, technological pedagogical knowledge, self-efficacy ICT, cooperative mindsets, and team leadership were statistically significant during the first three years in teacher education. For elaboration, self-regulation, and negotiation, the changes were not statistically significant (Table 5 and Fig. 1). In the latent growth curve modeling, the intercept of means indicates the starting point of the average person in the first year. In our case, the highest first year average was for NEGO at 5.97, the lowest was for TPK at 2.94. Still, the slope of means, the average rate of change, were the highest for TPK and SE ICT. Similarly, for the intercept of variances indicating how much individuals differ in the first year, again the highest values were for TPK and SE ICT. For the slope of variances, how much individuals differ in their rate of change, the highest values were for the SE ICT and COOP. The interaction effect here is the interaction of three time points. The results showed that statistically significant changes, pre-service teachers gained more confidence, were again for the TPK and SE ICT.

From the perspective of learning skills, the changes were minimal. Assessments remained almost at the same level within all three measurements (Fig. 1). With critical thinking, the development was straightforward positive but small, evolving from 4.70 to 4.85 (mean change 0.15, growth rate 0.08, effect size  $f = 0.07$ ). Within the skills to use ICT in education, the development trends were different. At the first measurement points, technological pedagogical knowledge and self-efficacy ICT received the lowest scores ( $M = 2.95$  and  $M = 3.57$ ). Nonetheless, unlike learning skills, these areas had the highest gains; the development was straightforward positive. With technological pedagogical knowledge, the change was from 2.95 to 3.83 (mean change 0.88, growth rate 0.44, effect size  $f = 0.35$ ), and with self-efficacy ICT, the change was from 3.57 to 4.07 (mean change 0.50, growth rate 0.26, effect size  $f = 0.20$ ). The first measures concerning the areas of collaboration dispositions were high. Negotiation gained the highest assessment altogether ( $M = 5.97$ ). The changes remained minimal between measurements; the biggest change was for cooperative mindset (mean

change  $-0.20$ , growth rate  $-0.11$ , effect size  $f = 0.10$ ). Unlike other areas, changes were mainly negative; assessments were lower each year.

When considering the order, that is, from the lowest to the highest assessment, we can see that there is only one change within three measurements and with minimal changes (Fig. 1). At the first measurement, self-regulated learning ( $M = 4.81$ ) was assessed slightly above critical thinking (4.70). At the third measurement, critical thinking ( $M = 4.85$ ) was assessed slightly more strongly than self-regulated learning ( $M = 4.82$ ). The standard deviations among all areas of learning skills and collaboration dispositions (Table 6) remained low at each measurement—the highest value was 0.91 for critical thinking in T1 ( $SD = 0.91$ ) and lowest for negotiation in T2 ( $SD = 0.54$ ). However, with ICT in education, the standard deviation values were bigger during the whole period, from 1.00 (TPK T3) to 1.12 (TPK T1). This is important aspect especially when the scale for measuring the areas of ICT in education was from one to six, instead of from one to seven like in other areas.

In the final step, we looked at the correlation between the three measured core areas and between separate factors. Correlations were studied only at yearly levels, that is, the correlation between first-year, second-year, and third-year measurements, respectively. The correlation table with all correlations is reported as an appendix because of the size of the table. Altogether, the correlation of factors within the same core areas were stronger than between areas. Within learning skills, the correlation varied between .48 (CRI and SRL) to 0.61 (SRL1 and ELA1). Within the collaboration disposition, the correlations varied from 0.24 (LEAD2 and NEGO2) to 0.52 (LEAD3 and COOP3). Within the skills to use ICT, the correlations varied from 0.55 (SE ICT 1 and TPK1) to 0.59 (SE ICT 3 and TPK3). When observing the changes within correlations among measured areas in ICT skills, the correlation became stronger each year. Within other areas, there was no such tendency. The correlations between the three core areas were lower or even negative. The highest correlation between areas was between NEGO1 and ELA1 (0.35); the lowest was with COOP2 and ELA2 ( $-0.11$ ).

#### 5. Discussion

The aim of this study was to provide insights into the development of pre-service teachers' perceptions of their 21st-century skills. Within the three general related areas (i.e., learning skills, collaboration dispositions, and skills to use ICT in education), the results indicate differences between the measured areas. Pre-service teachers entered teacher education confident in their learning skills, with positive dispositions toward collaboration. The results indicate that, despite university studies, the assessments within these areas remained at the same level during the three years of teacher education. The changes between measurement points were minimal. However, when considering skills to use ICT as the starting point, the development trends were different. The starting level was lower than the other two core areas, and the changes between the three measurement points were bigger.

For collaboration dispositions, the changes were minimal and mainly negative throughout the bachelor's degree program. Reasons for these results pose further questions. Within Finnish teacher training, the collaborative learning practices are emphasized. Reason for this negative tendency may be caused by challenges within the practical arrangements of collaborative learning such as organizing timetables, free-riding, team conflicts. Also, it may be that the collaborative learning practices are in an overemphasized position, suggesting a need for versatile teaching and learning methods used. The result aligns with Schussler (2006), who suggested that dispositions are relatively stable. Comparing these findings to results by Vermunt and Endedijk (2011),

**Table 4**  
Model fit information of latent growth curve modeling.

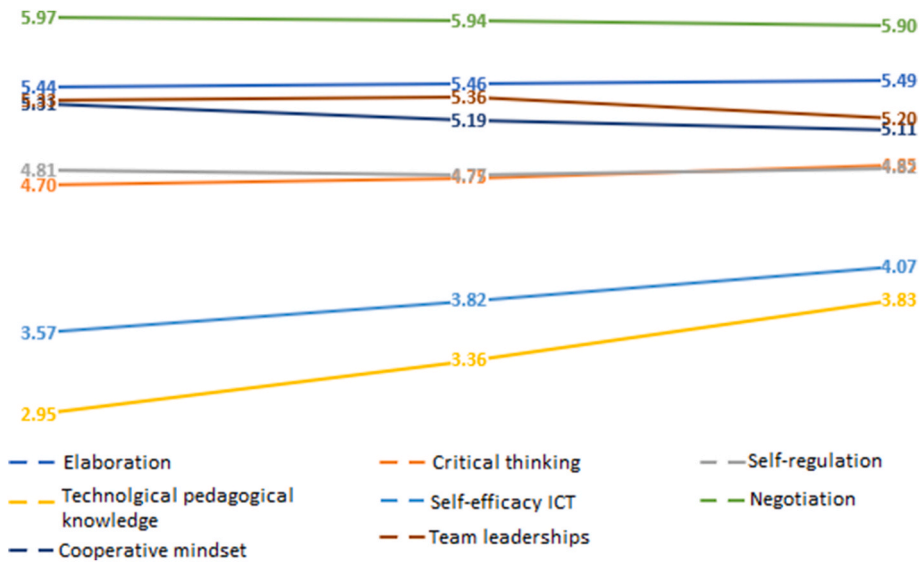
	Global fit indices						
	Chi-square test of model fit			CFI	TLI	RMSEA	SRMR
	df	$\chi^2$	p				
ELA	1	0.093	0.7605	1.000	1.000	0.000	0.004
CRI	1	0.033	0.8567	1.000	1.000	0.000	0.002
SRL	1	2.277	0.1313	0.995	0.984	0.063	0.015
TPK	1	0.027	0.8683	1.000	1.000	0.000	0.003
SE ICT	1	0.031	0.8607	1.000	1.000	0.000	0.002
NEGO	1	0.145	0.7029	1.000	1.000	0.000	0.006
COOP	1	0.081	0.7763	1.000	1.000	0.000	0.004
LEAD	1	4.216	0.0400	0.981	0.943	0.100	0.043

Note: CFI comparative fit index, TLI Tucker–Lewis index, RMSEA root-mean-square error of approximation, SRMR standardised root mean square residual. ELA elaboration, CRI critical thinking, SRL self-regulation, TPK technological pedagogical knowledge, SE ICT self-efficacy ICT, NEGO negotiation, COOP cooperative mindset, LEAD team leadership.

**Table 5**  
Parameter estimates for latent growth curve modeling.

	Means		Variances		Interaction effect	
	Intercept	Slope	Intercept	Slope	Intercept	Slope
ELE	5.43(0.04)***	0.04(0.03)	0.25(0.07)***	0.04(0.04)	0.01(0.00)***	0.00 (0.00)*
CRI	4.70(0.05)***	0.08(0.03)**	0.56(0.09)***	0.05(0.04)	0.01(0.00)***	0.00 (0.00)
SRL	4.79(0.04)***	0.02(0.02)	0.39(0.06)***	0.06(0.03)*	0.01(0.00)***	0.00 (0.00)
TPK	2.94(0.07)***	0.44(0.04)***	0.72(0.15)***	0.09(0.07)	0.37(0.03)***	0.18 (0.03)***
SE ICT	3.56(0.06)***	0.26(0.03)***	0.99(0.13)***	0.17(0.06)**	0.37(0.04)***	0.18 (0.03)***
NEGO	5.97(0.03)***	-0.03(0.02)	0.15(0.04)***	0.01(0.02)	0.01(0.00)***	0.00 (0.00)
COOP	5.30 (0.04)***	-0.11(0.03)***	0.43 (0.07)***	0.10(0.03)**	0.01(0.00)***	0.00 (0.00)
LEAD	5.35(0.04)***	-0.06(0.03)*	0.36(0.07)***	0.02(0.04)	0.01 (0.00)***	0.00 (0.00)

Note: \* $p < 0.05$ . \*\* $p < 0.01$ . \*\*\* $p < 0.001$ . ELA elaboration, CRI critical thinking, SRL self-regulation, TPK technological pedagogical knowledge, SE ICT self-efficacy ICT, NEGO negotiation, COOP cooperative mindset, LEAD team leadership.



**Fig. 1.** Changes in 21st-century skills. Note: Elaboration, Critical thinking, Self-regulation, Negotiation, Cooperative mindset and Team leadership were measured using 1 to 7 scale, Technological pedagogical knowledge and Self-efficacy ICT were measured using 1 to 6 scale.

**Table 6**  
Means, Standard Deviation, and Effect Sizes of Finnish pre-service teachers' 21st-century skills.

Core areas	21st- century skills	T1	T2	T3	Effect size			
		M(SD)	M(SD)	M(SD)	F (T1 vs T2)	F (T1 vs T3)	F (T2 vs T3)	F overall
Learning skills	ELA	5.44 (0.78)	5.46 (0.79)	5.49 (0.85)	0.01	0.02	0.01	0.02
	CRI	4.70 (0.91)	4.75 (0.90)	4.85 (0.88)	0.02	0.07	0.04	0.07
	SRL	4.81 (0.76)	4.77 (0.77)	4.82 (0.78)	0.02	0.01	0.02	0.02
Skills to use ICT	TPK	2.95 (1.12)	3.36 (1.04)	3.83 (1.00)	0.17	0.35	0.18	0.35
	SE ICT	3.57 (1.07)	3.82 (1.10)	4.07 (1.10)	0.10	0.20	0.09	0.20
Collaboration dispositions	NEGO	5.97 (0.57)	5.94 (0.54)	5.90 (0.70)	0.02	0.04	0.02	0.04
	COOP	5.31 (0.75)	5.19 (0.80)	5.11 (0.88)	0.06	0.10	0.04	0.10
	LEAD	5.33 (0.78)	5.36 (0.71)	5.20 (0.84)	0.01	0.06	0.07	0.08

Note: ELA elaboration, CRI critical thinking, SRL self-regulation, TPK technological pedagogical knowledge, SE ICT self-efficacy ICT, NEGO negotiation, COOP cooperative mindset, LEAD team leadership.

pre-service teachers can be seen as capable of applying several activities for regulating their learning and reflecting on their personal learning process (Endedijk et al., 2012). From the perspective of collaboration

dispositions, pre-service teachers can be expected to be willing to choose collaborative learning activities as part of their teaching practice (Altan et al., 2017; Tiilikainen et al., 2019). Again, when considering both

learning skills and collaboration dispositions, the effect of teacher training showed minimal changes; the levels of assessment remained the same throughout bachelor's degree studies. Both areas need further support in teacher education, since teacher beliefs and teacher self-efficacy are potential determinants of teachers' promotion of SRL and learning skills in their classrooms (Dignath, 2017).

From the perspective of skills to use ICT, the situation was different. Especially at the beginning of their studies, pre-service teachers did not seem confident in using ICT in education, that is, in combining their pedagogical knowledge with the possibilities provided by ICT (Koehler et al., 2013). Nonetheless, compared to learning skills and collaboration dispositions, it seems that teacher training had a very positive effect on the development of pre-service teacher perceptions of their skills for using ICT in education. Still, with ICT in education, the differences among respondents were bigger than within other areas, aligning with previous results by Valtonen et al. (2018). The results suggest that this could be a challenge for teacher education, especially when these differences seemed to remain big throughout bachelor's degree studies.

These results open new perspectives on how pre-service teachers perceive their 21st-century skills. Typically, 21st-century skills are described and listed as skills equally important for today's and the future's working life and as skills that need to be integrated into the curriculum (Häkkinen et al., 2017; Voogt & Roblin, 2012). From the perspective of pre-service teachers and teacher education, these areas pose highly different demands. These results can be seen aligning with previous TPACK studies, where participants were more confident in areas related to pedagogy than areas related to technology (Koh et al., 2010; Valtonen et al., 2018). One assumption from these results is that learning skills and collaboration dispositions can be seen as the *core* areas of the teaching profession, areas that are emphasized within teacher education and teacher education entrance exam literature. This may provide the starting point for first-year assessments and for the following years in teacher education. With ICT, the starting point and overall gains were different. The results indicate that the role of ICT in education showed not as taken for granted but, rather, as an area acknowledged during teacher education.

The results of this paper were based on pre-service teachers' self-assessments. Measurements were conducted with parts of the validated instruments allowing us to assume they are capable of capturing the development and evolution of pre-service teachers' perceptions of their 21st-century skills (cf. Naumann et al., 2019). This study did not contain any intervention toward developing certain 21st-century skills. Rather, the aim was to examine teacher education as a whole, wherein 21st-century skills are supposed to be integrated into everyday teaching. We assume that studies like this are needed more, focusing on different 21st-century skill areas. Similarly, more studies are needed for designing interventions and courses specially targeted for developing pre-service teachers' 21st-century skills, to provide them with positive perceptions of their skills. In the future, more studies are needed about pre-service teachers' 21st-century skills and the role of teacher education. Using conditional growth curve models with time-invariant and time-variant covariates, the factors affecting the development of pre-service teachers' perceptions of their 21st-century skills can be better outlined. Similarly, it will be important to see behind the numbers, that is, to use qualitative methods to see how the assessments actualize within concrete teaching practices and how pre-service

teachers can combine the measured areas in real teaching situations. In addition, for the future, an interesting question is why the measured areas remained separate throughout the bachelor's studies. ICT can be perceived as a hub of 21st-century skills, that is, used for supporting other 21st-century skill areas (Voogt & Roblin, 2012), creating expectations for a stronger relationship between the measured areas. Another important question will be the differences among pre-service teachers from the perspective of using ICT in education and how we can support the development of pre-service teachers who perceive their abilities to use ICT in education as low. This study was conducted using validated instruments from studies focusing on three selected areas. This provides starting points for the future to design new instruments for measuring 21st-century skills, that is, an instrument to cover other 21st-century skill areas. We assume this kind of instrument will be needed in teacher education to provide information and make visible the nature and development of pre-service teachers' 21st-century skills.

## 6. Conclusion

This paper provided an overview of the development of pre-service teachers' 21st-century skills within three Finnish universities. The results show that, from the perspective of pre-service teachers, the three areas appear different. The learning skills and collaboration dispositions show up as taken, with united and stable assessments, unlike skills to use ICT in education. Measured areas also show as separate entities, instead of closely related areas. We see the results providing important, new perspectives for the ways students perceive these skills, what kind of dispositions they have, and how these areas relate to 21st-century learning to evolve during teacher education. We assume these results need to be considered within teacher education, that is, how the challenges indicated can be better met within everyday teacher education practices.

## Author contribution

Teemu Valtonen, Conceptualization, Writing – original draft, Writing – review & editing, Formal analysis, Funding acquisition. Nhi Hoang, Formal analysis, Writing – review & editing. Erkko Sointu, Formal analysis, Data curation. Piia Näykki, Writing – original draft, Writing – review & editing. Anne Virtanen, Writing – original draft, Writing – review & editing. Johanna Pöysä-Tarhonen, Writing – Original, Draft Writing - Writing – review & editing. Päivi Häkkinen, Writing – original draft, Conceptualization, Project administration, Funding acquisition. Sanna Järvelä, Writing – original draft, Conceptualization, Project administration, Funding acquisition. Kati Mäkitalo, Writing – original draft, Conceptualization, Project administration, Funding acquisition. Jari Kukkonen, Writing – original draft, Writing – review & editing

## Acknowledgments

This work was supported by Suomen Akatemia/Academy of Finland [grant number 296799 and 273970].

**Appendix A. Correlation between 21st century skills in three different measurement points**

	ELA1	ELA2	ELA3	CRI 1	CRI 2	CRI 3	SRL1	SRL2	SRL T3	TPK1	TPK2	TPK3	NEGO1	NEGO2	NEGO3	COOP1	COOP2	COOP3	LEAD1	LEAD2	LEAD3	SEICT1	SEICT2		
ELA2	.507**																								
ELA3	.495**	.639**																							
CRI1	.520**	.386**	.355**																						
CRI2	.374**	.530**	.393**	.573**																					
CRI3	.278**	.438**	.566**	.580**	.602**																				
SRL1	.607**	.448**	.421**	.482**	.432**	.329**																			
SRL2	.359**	.600**	.489**	.307**	.507**	.450**	.611**																		
SRL3	.361**	.523**	.604**	.327**	.419**	.526**	.554**	.700**																	
TPK1	.084	.022	.126	.136*	.160*	.283**	.121*	.061	.203**																
TPK2	.157*	.153*	.220**	.149*	.257**	.183*	0.095	.075	.059	.474**															
TPK3	.043	.144	.221**	.154*	.285**	.298**	.147*	.169*	.258**	.380**	.514**														
NEGO1	.347**	.170*	.170*	.283**	.250**	.198**	.338**	.150*	.186**	.184**	.120	.048													
NEGO2	.157*	.230**	.148	.114	.234**	.091	.190**	.129	.065	.085	.176**	.104	.525**												
NEGO3	.194**	.221**	.335**	.252**	.203**	.266**	.235**	.124	.249**	.126	.132	.169*	.538**	.597**											
COOP1	.149**	-.023	.039	.130*	.144*	.118	.260**	.129	.183**	.216**	.098	.100	.456**	.220**	.220**										
COOP2	-.084	-.022	-.114	-.030	.079	-.046	.020	.011	-.029	.081	.150**	.023	.190**	.326**	.160*	.611**									
COOP3	-.019	-.033	.042	-.035	.029	.038	.056	.009	.106	.073	.145	.143*	.239**	.267**	.327**	.475**	.636**								
LAED1	.213**	.054	.120	.292**	.257**	.214**	.130	.156*	.188**	.085	.083	.347**	.158*	.258**	.158*	.307**	.243**								
LEAD2	.025	.064	.021	.037	.187**	.146	.101	.114	.103	.031	.081	.009	.124	.239**	.069	.422**	.504**	.583**							
LEAD3	.029	-.012	.168*	.114	.151	.270**	.134	.126	.169*	.023	.030	.140*	.155*	.100	.326**	.308**	.396**	.529**	.579**						
SEICT1	.043	.016	.108	.039	.074	.133	.060	.044	.080	.546**	.438**	.299**	.047	.030	.021	.133*	.116	.072	.130*	.110	.009				
SEICT2	.131	.105	.154*	.080	.230**	.148	-.014	.015	-.114	.412**	.562**	.386**	.087	.076	.070	.022	.079	.037	.115	.081	.041	.678**			
SEICT3	.046	.153*	.237**	.046	.172*	.274**	.014	.045	.127	.395**	.453**	.587**	.045	.040	.099	.083	.031	.076	.062	.000	.068	.533**	.720**		

\*\* Correlation is significant at the 0.01 level.

\* Correlation is significant at the 0.05 level.

**References**

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211.

Ajzen, I. (2002). Perceived behavioural control, self-efficacy, locus of control, and the theory of planned behaviour. *Journal of Applied Social Psychology*, 32, 665–683.

Altan, S., Lane, J., & Dottin, E. (2017). Using habits of mind, intelligent behaviours, and educational theories to create a conceptual framework for developing effective teaching dispositions. *Journal of Teacher Education*. <https://doi.org/10.1177/0022487117736024>. Advance online publication.

Ananiadou, K., & Claro, M. (2009). *21st-century skills and competences for new millennium learners in OECD countries*. Organisation for Economic Co-operation and Development.

Aslan, S. (2015). Is learning by teaching effective in gaining 21<sup>st</sup>-century skills? The views of pre-service science teachers. *Educational Sciences: Theory and Practice*, 15(6), 1441–1457.

Bedir, H. (2019). Pre-service ELT teachers' beliefs and perceptions on 21st-century learning and innovation skills (4Cs). *Journal of Language and Linguistic Studies*, 15(1), 231–246.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, 107(2), 238–246.

Bentler, P. M. (1995). *EQS structural equations program manual*. Multivariate Software.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st-century skills* (pp. 17–66). Springer.

Buzza, D., & Allinotte, T. (2013). Pre-service teachers' self-regulated learning and their developing concepts of SRL. *Brock Education*, 23(1), 58–76.

Dignath, C. (2017). What determines whether teachers enhance self-regulated learning? Predicting teachers' reported promotion of self-regulated learning by teacher beliefs, knowledge, and self-efficacy. *Frontline Learning Research*, 4(5), 83–105.

Endeldijk, M. D., Vermunt, J. D., Verloop, N., & Brekelmans, M. (2012). The nature of student teachers' regulation of learning in teacher education. *British Journal of Educational Psychology*, 82(3), 469–491.

Finnish National Board of Education. (2014). *National core curriculum for basic education 2014*, 96.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, 34, 906–911.

Fransen, J., Weinberger, A., & Kirschner, P. A. (2013). Team effectiveness and team development in CSCL. *Educational Psychologist*, 48(1), 9–24.

Gauvain, M. (2018). Collaborative problem solving: Social and developmental considerations. *Psychological Science in the Public Interest*, 19(2), 53–58. <https://doi.org/10.1177/1529100618813370>

Gloger, I., Schwonke, R., Holzäpfel, L., Nückles, M., & Renkl, A. (2012). Learning strategies assessed by journal writing: Prediction of learning outcomes by quantity, quality, and combinations of learning strategies. *Journal of Educational Psychology*, 104, 452–468.

Gordon, S., Dembo, M., & Hocevar, D. (2007). Do teachers' own learning behaviors influence their classroom goal orientation and control ideology? *Teaching and Teacher Education*, 23(1), 36–46.

Gordon, J., Halasz, G., Krawczyk, M., Leney, T., Michel, A., Pepper, D., & Wiśniewski, J. (2009). *Key competences in Europe. Opening doors for lifelong learning (Report No. 87)*. CASE—Center for Social and Economic Research.

Graesser, A., Kuo, B.-C., & Lai, C.-H. (2017). Complex problem solving in assessments of collaborative problem solving. *Journal of Intelligence*, 5(10), 10.

Griffin, P., Care, E., & McGaw, B. (2012). The changing role of education and schools. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st-century skills* (pp. 17–66). Springer.

Gustavson, K., von Soest, T., Karevold, E., & Røysamb, E. (2012). Attrition and generalizability in longitudinal studies: Findings from a 15-year population-based study and a Monte Carlo simulation study. *BMC Public Health*, 12(1), 918.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher–students for twenty-first-century learning practices (PREP 21): A framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching*, 23(1), 25–41.

Harris, J., Phillips, M., Koehler, M., & Rosenberg, J. (2017). TPCK/TPACK research and development: Past, present, and future directions. *Australasian Journal of Educational Technology*, 33(3), i–viii.

Hu, L., & Bentler, P. M. (1999). Cut-off criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, 6(1), 1–55.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content (TPACK)? *Journal of Education*, 193(3), 13–19.

Koh, J., Chai, C. S., & Tsai, C. C. (2010). Examining the technological pedagogical content knowledge of Singapore preservice teachers with a large-scale survey. *Journal of Computer Assisted Learning*, 26(6), 563–573.

Littleton, K., & Mercer, N. (2013). *Interthinking: Putting talk to work*. Routledge.

Metsämuuronen, J. (2003). *Tutkimuksen tekemisen perusteet ihmistieteissä 2 [Basics of research in social sciences, researcher's edition]*. Gummerus Kirjapaino Oy.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017.

Naumann, A., Rieser, S., Musow, S., Hochweber, J., & Hartig, J. (2019). Sensitivity of test items to teaching quality. *Learning and Instruction*, 60, 41–53.

Nissim, Y., Weissbluth, E., Scott-Webber, L., & Amar, S. (2016). The effect of a stimulating learning environment on pre-service teachers' motivation and 21st-century skills. *Journal of Education and Learning*, 5(3), 29–39.

- OECD. (2017). Pisa 2015 collaborative problem solving framework. <https://www.oecd-ilibrary.org/docserver/9789264281820-8-en.pdf?expires=1586252104&id=id&acname=guest&checksum=645BF50449F7D8F613A5A074C90BAD57>.
- O'Donnell, A. M., & Hmelo-Silver, C. E. (2013). Introduction: What is collaborative learning? An overview. *The international handbook of collaborative learning*, 1–15.
- P21Skills. (2013). 21st-century student outcomes and support systems. Retrieved January 2016 from <http://www.p21.org/our-work/p21-framework>.
- Perry, N. E. (1998). Young children's self-regulated learning and contexts that support it. *Journal of Educational Psychology*, 90(4), 715–729.
- Pintrich, P. R. (2000). Role of goal orientation in self-regulated learning. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 452–494). Academic Press.
- Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated for learning strategies questionnaire (MSLQ). *Educational and Psychological Measurement*, 53(3), 801–814.
- Proctor, B. E., Prevatt, F. F., Adams, K., Hurst, A., & Petscher, Y. (2006). Study skills profiles of normal-achieving and academically struggling college students. *Journal of College Student Development*, 47(1), 37–51.
- Rotherham, A. J., & Willingham, D. (2009). 21st-century skills: The challenges ahead. *Educational Leadership*, 67(1), 16–21.
- Scardamalia, M., Bransford, J., Kozma, B., & Quellmalz, E. (2012). New assessments and environments for knowledge building. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st-century skills* (pp. 231–300). Springer Netherlands.
- Schunk, D., & Greene, J. (2017). Historical, contemporary, and future perspectives on self-regulated learning and performance. In D. Schunk, & J. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 1–15). Routledge.
- Schussler, D. L. (2006). Defining dispositions: Wading through murky waters. *The Teacher Educator*, 41(4), 251–268.
- Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1–21.
- Silva, E. (2009). Measuring skills for 21st-century learning. *Phi Delta Kappan*, 90(9), 630–634.
- Steiger, J. H. (1990). Structural model evaluation and modification: An interval estimation approach. *Multivariate Behavioral Research*, 25(2), 173–180.
- Tait, H., & Entwistle, N. J. (1996). Identifying students at risk through ineffective study strategies. *Higher Education*, 31(1), 97–116.
- Teo, T., & Lee, C. B. (2010). Explaining the intention to use technology among student teachers: An application of the theory of planned behavior (TPB). *Campus-Wide Information Systems*, 27(2), 60–67.
- Teo, T., & Van Schaik, P. (2012). Understanding the intention to use technology by preservice teachers: An empirical test of competing theoretical models. *International Journal of Human-Computer Interaction*, 28(3), 178–188.
- Tiilikainen, M., Toom, A., Lepola, J., & Husu, J. (2019). Reconstructing choice, reason and disposition in teachers' practical theories of teaching (PTs). *Teaching and Teacher Education*, 79, 124–136.
- Toom, A. (2017). Teacher's professional and pedagogical competencies: A complex divide between teacher's work, teacher knowledge, and teacher education. In D. J. Clandinin, & J. Husu (Eds.), *The SAGE handbook of research on teacher education* (Vol. 2, pp. 803–819). SAGE.
- Tucker, L. R., & Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika*, 38, 1–10.
- Valtonen, T., Kukkonen, J., Kontkanen, S., Mäkitalo-Siegl, K., & Sointu, E. (2018). Differences in pre-service teachers' knowledge and readiness to use ICT in education. *Journal of Computer Assisted Learning*, 34(2), 174–182.
- Valtonen, T., Kukkonen, J., Kontkanen, S., Sormunen, K., Dillon, P., & Sointu, E. (2015). The impact of authentic learning experiences with ICT on pre-service teachers' intentions to use ICT for teaching and learning. *Computers & Education*, 81, 49–58.
- Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology*, 33(3), 15–31.
- Vermunt, J. D., & Endedijk, M. D. (2011). Patterns in teacher learning in different phases of the professional career. *Learning and Individual Differences*, 21(3), 294–302.
- Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of 21st century. *Journal of Computer Assisted Learning*, 29(5), 403–413.
- Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st-century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, 44(3), 299–321.
- Wang, L., MacCann, C., Zhuang, X., Lydia, L. O., & Roberts, D. R. (2009). Assessing teamwork and collaboration in high school students: A multimethod approach. *Canadian Journal of School Psychology*, 24(2), 108–124.
- Weinstein, C. E., Husman, J., & Dierking, D. R. (2000). Self-regulation interventions with a focus on learning strategies. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 727–747). San Diego, CA, US: Academic Press.
- Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Mahwah, NJ: Lawrence Erlbaum Associates.
- Winne, P. H., & Perry, N. E. (2000). Measuring self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 531–566). San Diego, CA, US: Academic Press.
- Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press.
- Zimmerman, B. J., & Schunk, D. H. (2011). Self-regulated learning and performance. In B. J. Zimmerman, & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 1–12). New York: Routledge.