



Research paper

Future teachers' self-efficacy in teaching practical and algorithmic ICT competencies – Does background matter?

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ABSTRACT

Future teachers need to be confidently equipped to teach 21st century ICT skills. We investigated teaching self-efficacy (TSE) in ICT competencies among teacher students. We confirmed distinct ICT competencies among two cohorts from teacher training programs ($n = 347$; $n = 428$): practical (i.e., device and data management), and algorithmic (i.e., programming, and data security). Regression analyses indicated TSE-biases regarding younger age, male gender, and a background in natural sciences, with significant interactions between age, gender, and having learned such ICT-skills already in school. The findings point to a need for tailored strategies in teacher education to mitigate TSE disparities.

1. Introduction

Algorithms, the computer formulas that concurrently influence how we think and communicate on social media sites, controlled by major businesses, are a topic of widespread debate. Often appearing as black boxes to their users, the algorithms of the most popular social media platforms (e.g., Facebook, Instagram, X, TikTok) are both pervasive and persuasive, as well as increasingly intelligent. Unfortunately, they are often closely connected to certain powerful actors that may intentionally aim to create confusion and instability worldwide by polarizing discussions (Kim, 2017; Melin, 2021). Questions of digital sustainability, i.e., of the potential erosion of democracy through digitally hyper-targeted propaganda and the rise of the surveillance state, are also more pressing than ever (Harari, 2023; Messner et al., 2019). At the end of the day, this a serious threat for stability and even world peace.

The landscape of this globally networked, digital information society requires new kinds of literacies and competencies for us to achieve full agency and build a collectively sustainable, digitalized future (e.g., Benander, 2018; Berger & Frey, 2015; Ntiri, 2009; Redecker & Punie, 2017). We cannot leave young people without the support of formal education in this novel, digital sphere of polarizing state and data market influences with profound effects on their lives and welfare (Beyens et al., 2016; Castrén et al., 2022; Kelly et al., 2018; Srnicek, 2017; Waterson & Milmo, 2021). Mature teachers may have trouble

staying on track, but even the young pre-service teachers, who are supposed to be among the so-called “digital natives” (Prensky, 2001) have challenges in keeping up with the multitude of rapidly evolving and expanding digital systems around us. Alarming inequalities or a “digital divide” (Van Dijk, 2020) has been discovered in the digital readiness between genders (favoring males; Askar & Davenport, 2009; Busch, 1995; Luxton-Reilly et al., 2018) and socioeconomic backgrounds (favoring the advantaged; Chiao & Chiu, 2018; Claro et al., 2015; Vekiri, 2010) in an increasing rate globally. At schools, teachers are key players in helping all their pupils develop the necessary competencies to tackle these urgent challenges (Messner et al., 2019). Therefore, future teachers' self-efficacy (Bandura, 1997) in their ability to support the pupils in these socio-digital competencies (i.e., teaching self-efficacy, TSE; Dassa & Nichols, 2019) is an important, understudied topic of research.

The context of the present study is Finland, where, as in many other countries, understanding and utilizing information and communication technology (ICT) is indeed recognized as a crucial skill in the basic education curriculum (Finnish National Agency for Education [FNAE], 2014). ICT is considered both a substantial topic of learning and a significant educational tool, laying the foundation for what is referred to as multiliteracy in the 21st century (Cope & Kalantzis, 2013; FNAE, 2014). The expectation is that digital competencies should be woven into various subjects and educational levels, fostered through

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interdisciplinary projects, and integrated into other academic activities (Lonka, 2018). Such competencies also include programming and algorithmic thinking, which are also viewed as essential (FNAE, 2014). It is imperative that all students acquire these skills by the end of their basic education. As a result, it is the collective responsibility of all teachers to ensure students develop these competencies (FNAE, 2014; Lonka, 2018).

In order to examine the readiness of future teachers to teach the already urgently needed ICT competencies, this study sheds light on teacher students' domain-specific teaching self-efficacy (Study I; Bandura, 1997; Dassa & Nichols, 2019). It also addresses their own formal education and schooling in these competencies as well as gender and age differences in their teaching self-efficacy and personal self-efficacy (Study II).

1.1. Algorithmic thinking and programming skills

Computational thinking (CT)¹ refers to the application of mental tools, concepts, practices, and perspectives of computer science (and more specifically computer programming) to solving problems, developing solutions and understanding human behavior (Brennan & Resnick, 2012; Wing, 2006). In practice, these solutions are constructed as *algorithms*, i.e., logical, sequential instructions to implement with a computer or another information processing agent (note: the definition also covering, e.g., humans; Wing, 2006; hence, the other, more or less equivalent term to CT: algorithmic thinking), thus raising to an essentially higher level of abstraction in comparison with the simple end user manipulation of the pre-created user interfaces of digital software. CT is integral to the research and problem-solving work in the increasingly influential modern day STEM fields (Science, Technology, Engineering and Mathematics; Tang et al., 2020).

Today's learners are constantly using digital tools and service ecosystems from companies like Meta, Google, and Microsoft. This makes it essential for them to develop computational thinking (CT) skills to navigate their everyday lives (Waterson & Milmo, 2021). Thus, multiple scholars and the community have argued for the introduction of CT to K-12 education (Barr & Stephenson, 2011; Grover & Pea, 2013; Sengupta et al., 2013; Wing, 2006; Yadav et al., 2016). Certain learning benefits have also been presented in utilizing CT in more advanced science and mathematics reasoning (Ateşkan & Hart, 2021; Blikstein & Wilensky, 2009; Wing, 2006). However, earlier research has found CT to still appear fairly mysterious to teacher candidates in general (Ateşkan & Hart, 2021; McDonald, 2017; Rich et al., 2021).

Coding and computer programming refer to the practical implementation of algorithms in a digital format. Rich et al. (2021) investigated teacher beliefs about coding and CT, and found these two somewhat separate constructs. They call for further research on the interplay of the related self-efficacies (Bandura, 1997). Thus, it needs to be recognized that even these specific skills have their own, sub-level conceptual structure. In the context of the present study, Finland, when it comes to CT, the national core curriculum of basic education highlights the skills of *algorithmic thinking* and *programming* in its different sections (FNAE, 2014). We will thus use the term "*algorithmic*" in the paper to refer to the more conceptual ICT competencies.

1.2. Self-efficacy in ICT competencies and the related background factors

Social cognitive theory first introduced the concept of *self-efficacy* (SE,² Bandura, 1997; 1989) as a person's confidence in their ability to carry out a task or action. It is notable that this does not necessarily correlate one-to-one with their factual ability, or *efficacy*, in the given task. Earlier research has confirmed domain-specific rather than general

self-efficacy to be more relevant for achievement in a given domain, even on the level of very specific tasks (i.e., "*I can download a file*"; Klassen & Chiu, 2010; Rohatgi et al., 2016). This has indeed been the mentality of previous research on ICT education, much of which has focused on measuring self-efficacy. In fact, in a systematic review on introductory programming education by Luxton-Reilly et al. (2018), self-efficacy alone was found, so far, to be the most researched factor regarding programming attitudes. Self-efficacies in basic (e.g., using the internet) and advanced ICT competencies (e.g., programming and building webpages) have earlier been found distinct constructs (Fraillon et al., 2014; Rohatgi et al., 2016; Tømte & Hatlevik, 2011).

Rohatgi et al. (2016) summarized the positive correlations between computer and information literacy as well as ICT self-efficacy and ICT usage frequency, although earlier research tends to be very context specific (Rohatgi et al., 2016). They also found that school related ICT use was not related to self-efficacies in basic or more advanced ICT competencies, and only recreational use provided the pupils with ICT-related mastery experiences (Tømte & Hatlevik, 2011). Also, Halonen et al. (2016) found that, in the Finnish context, 6th grade pupils reported that their teachers were able to support them in all areas of learning except for digital engagement. Compeau and Higgins (1995) conceptualized general computer self-efficacy as "*a judgment of one's capability to use a computer*", thus referring to mainly the basic-level skills of the ICILS-framework (the International Computer and Information Literacy Study, e.g., Fraillon et al., 2014; Rohatgi et al., 2016; Tømte & Hatlevik, 2011). The high correlations of actual ICT literacy and self-efficacy have been well documented on a student level (Fraillon et al., 2014; Hohlfield et al., 2013).

Gender differences have been documented in earlier research on ICT and programming self-efficacy repeatedly and extensively (Luxton-Reilly et al., 2018). ICT self-efficacy has generally been found to be higher in males than females (Busch, 1995; Askar & Davenport, 2009), although Fraillon et al. (2014) found the difference to be relevant only in advanced ICT tasks (i.e., programming) and females, in fact, bested males in more basic task related self-efficacies. They also documented males' generally greater interest in and enjoyment of ICT use, although there was no significant difference in usage frequency at home or school, and the females more often tended to attribute their ICT learning to school instruction. Askar and Davenport (2009) also found that 12 percent of the variance in programming self-efficacy could be explained by formal instruction. Similarly, as has been found regarding other STEM-fields, it is highly likely that stereotype threats (Shapiro & Williams, 2012) play a part in the reinforcement of the gender imbalance regarding females' self-efficacy in ICT.

In addition to gender and formal instruction, other factors that have been found significant regarding programming self-efficacy and learning are math background, comfort or anxiety level during a programming course, as well as attributional and motivational factors (both intrinsic and extrinsic; Law et al., 2010; Torkzadeh et al., 2006; Wilson & Shrock, 2001). Age has also been found to play a minor role in programming self-efficacy, however, so far without practical educational significance (i.e., the difference is nothing that cannot be overcome by targeted educational interventions; Saeli et al., 2011; Sethuraman & Medley, 2009; Sorva, 2012). Regarding the more basic ICT skills, low socioeconomic background is an unfortunate issue more often affecting ICT literacy than, for example, reading or mathematics competence (Claro et al., 2015; Vekiri, 2010).

1.3. Teachers' self-efficacy in the teaching of ICT competencies

Teachers' *teaching self-efficacy* (TSE)³, alongside their pedagogical content knowledge (Shulman, 1986), has been found to be a crucial factor influencing their performance (Dassa & Nichols, 2019;

¹ CT = Computational Thinking.

² SE = Self-Efficacy.

³ TSE = Teaching Self-Efficacy.

Lauermann & ten Hagen, 2021). According to some earlier research, TSE should be assessed to reflect functioning within a particular domain (Klassen & Chiu, 2010; Lee & Tsai, 2010) instead of a general teaching ability (i.e., Tschannen-Moran & Hoy, 2001; Malinen et al., 2013). In order to assess teachers' strengths and preparedness to the schools of the future and to implement the modern curricula, the TSE of preservice teachers is of particular interest (Çakiroglu et al., 2005).

A teacher's personal self-efficacy has far-reaching consequences for student learning, as has been found also regarding ICT competencies and their instruction: In case the teacher lacks self-efficacy, their pupils may gain negative mastery experiences of the topic as well (Israel et al., 2015). On the other hand, it is important to recognize that the teacher might have, for instance, low personal self-efficacy in ICT (e.g., algorithmic thinking; Wing, 2006) but high *teaching* self-efficacy regarding it (Rich et al., 2021). It is notable that some of the theoretical and mathematical content related to the algorithmic realm can also be developed without computers or by using didactic teaching (e.g., Kruskopf et al., 2019; 2021b). According to Koehler and Mishra's (2009; 2005) framework of technological-pedagogical content knowledge (TPACK, based on Shulman's pedagogical content knowledge, 1986; Hsu et al., 2020) this can be considered as theoretical or content knowledge related to technology, which is in contrast to technological pedagogical knowledge related to supporting the learning process with technology on the teacher's behalf (Koehler & Mishra, 2005, 2009). In a study by Sang, Valcke, Van Braak, and Tondeur (2010), it was found that teachers' prospective ICT integration depends on their computer and teaching self-efficacies along with computer attitudes (e.g., so-called technology acceptance; Teo et al., 2008) and constructivist teaching beliefs (Sang et al., 2010). Kent and Giles (2017) examined preservice teacher technology self-efficacy and found that most teachers already incorporate technology into their lesson plans with high confidence in their ability to utilize technology, across the curriculum. However, one study found that only 30 % of (in-service) teachers felt competent in teaching computer programming (McDonald, 2017; Rich et al., 2021).

1.4. ICT competencies in the context of the Finnish school

In Finland, the National Core Curriculum for Basic Education (Finnish National Board of Education, FNAE, 2014) and the National Curricula for Upper Secondary Education (FNAE, 2020) are obligatory documents guiding basic education and upper secondary education nation-wide. The implementation of the former started from sixth grade in 2016, whereas the latter in 2021. Along the lines of global trends in curricular development emphasizing more generalizable competencies, attitudes, and values, so-called "future skills" or "21st century competencies" (Berkowitz & Miller, 2018; Bialik & Fadel, 2018; Brown, Harris & Russel, 2010; Cedefop, 2012; Haste, 2018; Heckman & Kautz, 2012; Laukkonen et al., 2018; Luckin & Issroff, 2018; Messner et al., 2019), both curricula introduced their own frameworks for "transversal competencies". These competencies are obligatory for every teacher to consider in their instruction. The National Core Curriculum for Basic Education (FNAE, 2014) introduced altogether seven distinctive transversal competence themes: 1) thinking and learning to learn, 2) cultural competence, interaction and self-expression, 3) self-care and managing everyday life, 4) multiliteracy, 5) ICT competence, 6) working life skills and entrepreneurship and 7) participating, influencing and building a sustainable future. Thus, as recommended also by the European Union (Redecker & Punie, 2017), ICT competencies are recognized as a necessity in our changing world.

Along with multiple other topically debated phenomena, the role of digital technologies, or "Information and Communication Technologies" (ICTs), as they are referred to in the Finnish curricula, has not been defined on a subject matter -level (the subject matter status of ICT-related knowledge and skills are locally decided as individual selective courses). Instead, the role of information technologies is highlighted throughout the curricula of basic education including its own sub-area

within the transversal competencies. Regarding the necessity of establishing a sustainable lifestyle on a societal level, we have the "*responsibility to guide the development of technology into a direction that guarantees the future of humankind and nature*" (FNAE, 2014, p. 16). The role of ICT as a solution to problems as well as a problem to be solved in itself is thus very much emphasized (Messner et al., 2019). In addition, there are specific references to ICT in the sections regarding the operational culture of the Finnish school, learning environments and working methods as well as equalizing distance learning and evaluation practices (FNAE, 2014). These principles are already very much researched and established in very profound theoretical frameworks (e.g., Paavola et al., 2004; Paavola & Hakkarainen, 2014).

Within the transversal competence area of ICT, the four central sub-themes specified in the Finnish curricula are 1) using and producing (digital artefacts), 2) responsible and safe digital conduct, 3) inquiry-based, creative working and data management, as well as 4) interaction and networking (FNAE, 2014). These are separately specified for different grade levels. In addition to the explicit area of ICT competence and multiliteracy, technology is also mentioned important regarding the competencies of thinking and learning to learn as well as managing everyday life in the digitalized environment. Societal changes brought about by technological development are also briefly recognized within working life competencies. ICT enhances the pupils' general sense of agency in their environment, creativity, learning, and gaining insights through documenting and visualizing their own thinking processes (FNAE, 2014).

Regarding the role of computational competencies in Finnish elementary school curricula (FNAE, 2014), these are gradually introduced to the students from the first grade onwards (at approximately age seven) through what is referred to in the curricula as "*algorithmic thinking and programming skills*". They are associated most closely with the mathematics subject matter (as has been recommended in some studies, i.e., Ateşkan & Hart, 2021; Hambruch et al., 2009; Sengupta et al., 2013). The coding skills gradually deepen throughout basic education from graphical programming (grade six) to textual interfaces (grade nine; FNAE, 2014). Within the transversal competence objectives through grades seven-to-nine, it is also mentioned that the pupils' "*conceptions of the internal usability and functioning logic of different devices and applications deepens. They practice systemizing, organizing and sharing files as well as producing different digital products independently as well as collaboratively. Programming is practiced throughout different subject matter studies.*" (FNAE, 2014, p. 284). Thus, all subject matter teachers are required to either know the basics of programming themselves or, alternatively, utilize multidisciplinary expertise of their colleagues with the aid of interdisciplinary or phenomenon-based projects (Lonka, 2018). Within the specific objective of mathematics subject matter, computational competencies are considered to include not only the transversal competence area of ICT, but also those of thinking and learning to learn, multiliteracy, and working life competencies (FNAE, 2014).

The report of Finnish Education Evaluation Centre (FEEC, Saarinen et al., 2021) indicated that the implementation of transversal competencies in basic education has been problematic. The goals of the competency skillset were considered ambiguous and difficult to accomplish in practice. The same report suggested that there is a need to define the central concepts more clearly both at the national and local level. Long-term support and in-service training for implementation was specifically called for, as well (see also Kauppinen et al., 2021).

1.5. Research aims

In order to examine future teachers' readiness to teach 21st century ICT competencies, this study sheds light on Finnish teacher students' teaching self-efficacy (TSE). We also address the teacher students' personal self-efficacy and examine their previous, school-related mastery experiences in the 21st century competencies and ICT competencies. In

the paper we present two separate studies with their respective datasets. This is due to the new discoveries made already during the data collection process, which led us to expand the survey instrument further by adding the new variables of personal self-efficacy and previous formal schooling in the competencies, which were examined in a new teacher student sample. The research questions of the studies were:

RQ1: Can we confirm two dimensions of teaching self-efficacy (TSE) in ICT competence (practical and algorithmic) within the seven-factor structure of 21st century competence in the Finnish curricula? (Study 1)

RQ2: To what extent do teacher students differ by age, gender, and preceding formal schooling in their a) *teaching self-efficacy* (TSE) and b) *personal self-efficacy* (SE) in the two ICT and other 21st century competencies? (Study 2)

2. Study 1: Two dimensions of teaching self-efficacy in ICT competencies: practical and algorithmic

2.1. Materials and methods

2.1.1. Participants and procedures

The participants of Study 1 were teacher students ($n = 347$, 83 % female, 16 % male and 1 % other, as acquired from self-report), who completed an introductory course in educational psychology in the academic year of 2019–2020 or 2020–2021. The convenience sample was acquired by encouraging voluntary survey participation among the whole class cohort of class and subject matter teacher education during the two implementations of this lecture course. The link to the mobile supported, pseudonymous survey, measuring the 21st century competencies alongside, e.g., study engagement and epistemic beliefs, was distributed to the students on their first lecture (in October 2019 and September 2020) and they were encouraged to fill in the survey before their second lecture. The data collection was carried out separately from the course exam. It was made explicit to the participants that the pseudonymous questionnaires had nothing to do with the completion of the course.

Half of the participants were new teacher students at the University of Helsinki who had begun their major between the fall of 2018 and 2020. Half of the students reported studying in the Bachelor's and 29 % in the Master's phase. Of the students, 29 % reported studying to become subject matter teachers, 28 % to become primary school teachers and the rest specialized in other forms of teaching (i.e., special education or adult education). The ages of the participants ranged from 19 to 49 years, the median being 25, mean 29 and standard deviation 8 years.

2.1.2. Measures

The 21st century competence –measure used in the study is presented in more detail by Ranta et al. (2022). A list of the competencies assessed is presented in Table 1. In the survey introduction, the respondent was asked “What do you think about teaching/instructing the following matters” and the response options defined as “1 = Completely disagree, 2 = Disagree, 3 = Partially disagree, 4 = Partially agree, 5 = Agree, 6 = Completely agree”. The measure included an item of teaching self-efficacy (“I’m good at instructing this”) assessed with a six-point Likert-scale (with reminders: 1 = “completely disagree” – 6 = “completely agree”) on the 41 competencies initially grouped under each of the seven curricular transversal competence themes (T1–T7; FNAE, 2014). The other expectancy-value variables measured (e.g., interest, importance, and extra cost, see Appendix A; Eccles-Parsons et al., 1983; see Ranta et al., 2022) are beyond the scope of this study. An example on how the items were displayed to the respondent is given in Appendix A. For example, the teacher student would be presented with a statement “Algorithmic thinking – I’m good at instructing this” (among the other questionnaire items regarding algorithmic thinking), and they would scale their agreeableness with the statement on the six-point

Table 1

The 21st century competencies measured in the questionnaire used in Study 1 and the shortened list used in Study 2, focusing on the ICT competencies (based on FNAE, 2014).

21st century competencies (Study 1)	21st century competencies (Study 2)
Theme 1 Q1 Thinking and Learning to Learn ^a Q2 Inquiry-based approach to learning ^a Q3 Critical thinking ^a Q4 Creative and insightful thinking Q5 Discovering your own strengths	Thinking and Learning to Learn
Theme 2 Q1 Cultural Competence, Interaction and Self-Expression ^a Q2 Self-awareness and emotional skills ^a Q3 Performing ^a	Cultural Competence, Interaction and Self-Expression
Theme 3 Q1 Self-Care and Managing Everyday Life Q2 Consumer skills Q3 Managing digitalized everyday life ^a Q4 Promoting well-being and health ^a Q5 General safety and acting in dangerous situations ^a Q6 Personal privacy ^a	Self-Care and Managing Everyday Life
Theme 4 Q1 Multiliteracy ^a Q2 Self-expression and communication ^a Q3 Scientific expression ^a	Multiliteracy
Theme 5 Q1 Information and Communication Technology Competence ^a Q2 Producing data ^a Q3 Data management ^a Q4 Acquiring data Q5 Managing hardware and software ^a Q6 Programming ^a Q7 Algorithmic thinking ^a Q8 Responsibility, law and copyrights ^a Q9 Security and risk management ^a	Information and Communication Technology Competence Producing data Data management Acquiring data Managing hardware and software Programming Algorithmic thinking Responsibility, law and copyrights Security and risk management Managing digitalized everyday life ^b
Theme 6 Q1 Working Life Skills and Entrepreneurship ^a Q2 Operating in a global environment ^a Q3 Entrepreneurial mindset Q4 Collaboration at work Q5 Working in projects ^a Q6 Networking Q7 Getting to know businesses and industries in the surrounding area Q8 Entrepreneurship	Working Life Skills and Entrepreneurship
Theme 7 Q1 Participating, Influencing and Building a Sustainable Future Q2 Developing the school environment ^a Q3 Influencing and working outside school Q4 Agency in a democratic society ^a Q5 Responsible decision-making ^a Q6 Acting according to rules and agreements Q7 Protecting the environment and building a sustainable future	Participating, Influencing and Building a Sustainable Future

^a Included in the final model on TSE in future skills.

^b Originally this item was considered part of T3.

Likert-scale.

2.1.3. Analyses

In order to examine the validity of the two dimensions of ICT competence within the 21st century competencies of the Finnish curriculum, we conducted second order Confirmatory Factor Analyses (CFA) on the 41 teaching self-efficacy (TSE) items based on the seven-factor structure of transversal competence in the Finnish curriculum. We split the ICT-competence into two, in line with the previous

observations made on the distinction between basic and advanced skills (Fraillon et al., 2014; Rohatgi et al., 2016; Tømte & Hatlevik, 2011).

We analyzed the model structure by means of CFA's, using maximum likelihood estimation with robust standard errors (MLR), which considers any skewness in the data with the scaling correction factor (scf). We took missing values into account with full information maximum likelihood (FIML). We examined model fit with the data as according to the relevant fit indices and suggested thresholds: Comparative Fit Index (CFI ≥ 0.95), Root Mean Square Error of Approximation (RMSEA ≤ 0.06), and Standardized Root Mean Square Residual (SRMR ≤ 0.08 ; Hu & Bentler, 1999). McDonald's Omegas were calculated as measures of internal consistency. The analyses were conducted with R statistical software (version 4.1.3, RStudio version 2022.07.1; Baldwin et al., 2010) and the complementary lavaan (Rosseel, 2012) and EFAtools packages (Steiner & Grieder, 2020). The descriptive statistics were acquired using IBM SPSS Statistics version 29.0.1.0.

2.2. Results

Table 2 displays the results of the tested second order models. We started out by testing the model of seven 21st century competencies assumed in the construction of the study's measure. This model fit the data slightly worse than an unmodified version of the theoretical model with the two separate ICT factors (the practical ICT competence with one item initially among T3, "self-care and managing everyday life" called "managing digitalized everyday life"). We thus proceeded to reduce the complexity of the eight-factor model by means of analyzing modification indices, and at all steps of complexity reduction, theoretical expectations guided the process. We achieved a good fit by conventional indices with a model including 35 items and two released residual covariances between items, and latent factors, respectively. In order to enhance the fit of the model to concurrent fit index standards, we proceeded to further reduce the complexity of the model. Fig. 1 shows the final modified eight-factor model, which achieved the best fit with the data. Additionally, we tested the second order fit of the two ICT competence dimensions individually, achieving fit by modern standards with the covariance between the two, tightly interconnected latents released. The descriptive statistics of the established latent factors are displayed in Table 3.

3. Study 2: Factors related to teaching self-efficacy in the ICT competencies

3.1. Materials and methods

3.1.1. Participants and procedures

The participants of Study 2 ($n = 428$, 77 % female, 18 % male, 2 % other, as acquired from self-report) were teacher students of the two, academic year 2021–2022 implementations of an introductory course in educational psychology at the University of Helsinki. The protocol of sample collection was identical to Study 1, and the survey links were distributed during the first lectures of the two course implementations (in September 2021, and November 2021). The survey measured the

21st century competencies alongside, e.g., study engagement and epistemic beliefs. Most of the participants had begun their university studies during the same fall the course was implemented, 2021. Over half, 60 %, of the students reported studying in their Bachelor's and 12 % in their Master's phase. Most of the students (38.5 %) reported studying in a subject matter pedagogic, 18.9 % in primary school teacher, 25.7 % in early childhood education programme, and the rest did not specify. The ages of the participants ranged from 19 to 61 years, the median being 24 and mean 27 ($SD = 8.3$). Regarding the subject matter teacher students in this study, 16 % studied to become language teachers, 7.5 % teachers of societal subjects, 12.1 % teachers of arts and crafts subjects, 3.5 % math teachers and 7.9 % teachers of other STEM subjects. They were from 6 different faculties at the University of Helsinki (note that the Finnish subject matter teachers generally go through Master's level training in their subject faculties and apply for the separate, 60 ECTS subject matter teacher programme). 10 % of the students came from STEM faculties (53.7 % female) and 90 % from the faculties of social-, humanistic, and education sciences (SHAPE, 83.8 % female).

3.1.2. Measures

In Study 2 we radically shortened and modified the 21st century competence questionnaire to include only the confirmed, curricular top-level themes (T1–7) and focused in more detail on the ICT competencies (the questions listed in the second column of Table 1). The same survey introduction and response options were presented as in Study 1. Along with a TSE item ("I'm good at instructing in this"), the survey included an additional item on personal self-efficacy (SE, "I'm good at this") as well as an item concerning the students' own schooling in these competencies ("I have learned this already at school"). A Likert-scale of 1–6 was deployed (1 = "completely disagree" – 6 = "completely agree"). An example on how these items were displayed to the respondent in the survey is given in Appendix C. For example, regarding programming the respondent would be displayed the three items "Programming – I'm good at this", "Programming – I'm good at instructing in this", and "Programming – I have learned this already at school". The participants reported their birth year, and their age was calculated by subtracting their birth year from the year of the survey submission. For analytical purposes, the participants were divided into three age categories: 18–21 (late adolescence – young adulthood; World Health Organization, 2001; $N = 124$), 21–31 (young adults, $N = 193$), 31–62 (adults, $N = 99$).

3.1.3. Analyses

With the sample of Study 2, we confirmed the two dimensions of ICT competence (practical and algorithmic) as well as a combined latent dimension of the other 21st century competencies (T1–T7, excluding ICT competence). To do this, we conducted separate CFAs with the three latent factors on the TSE, SE, and schooling items. To assess model fit, same criteria for fit index thresholds were used as in Study 1 (CFI ≥ 0.95 , RMSEA ≤ 0.06 , SRMR ≤ 0.08 ; Hu & Bentler, 1999). We calculated McDonald's Omegas as measures of internal consistency. These models were used to extract factor scores with regression method for moderation analyses.

To study the differences between teacher students in their TSE and

Table 2

Comparison of the different second order models of 21st century competence.

Model	χ^2	p	df	scf	CFI	RMSEA [CI]	SRMR	λ /Items	Cov.	AIC	BIC
Curricular Theoretical	2007.921	<0.001	733	1.187	0.818	0.077 [0.073, 0.081]	0.072	7/41	–	37807.021	23662.923
Unmodified	1950.090	<0.001	771	1.187	0.839	0.072 [0.068, 0.076]	0.073	8/41	–	38486.513	38990.775
Conventional	1066.817	<0.001	550	1.205	0.910 ^a	0.057 [0.052, 0.062] ^a	0.054 ^a	8/35	2	32788.543	33231.216
Modified	447.367	<0.001	263	1.211	0.952 ^a	0.049 [0.041, 0.057] ^a	0.048 ^a	8/25	4	23328.032	23662.923
Two ICT	37.368	<0.05	18	1.115	0.988 ^a	0.059 [0.031, 0.086] ^a	0.024 ^a	2/8	1	7321.483	7421.566

Notes: $n = 347$.

^a acceptable model fit by conventional indices. Cov. = the number of freed residual covariances. Robust fit indices. λ depicts the number of first order factors, each mode additionally includes one second order factor.

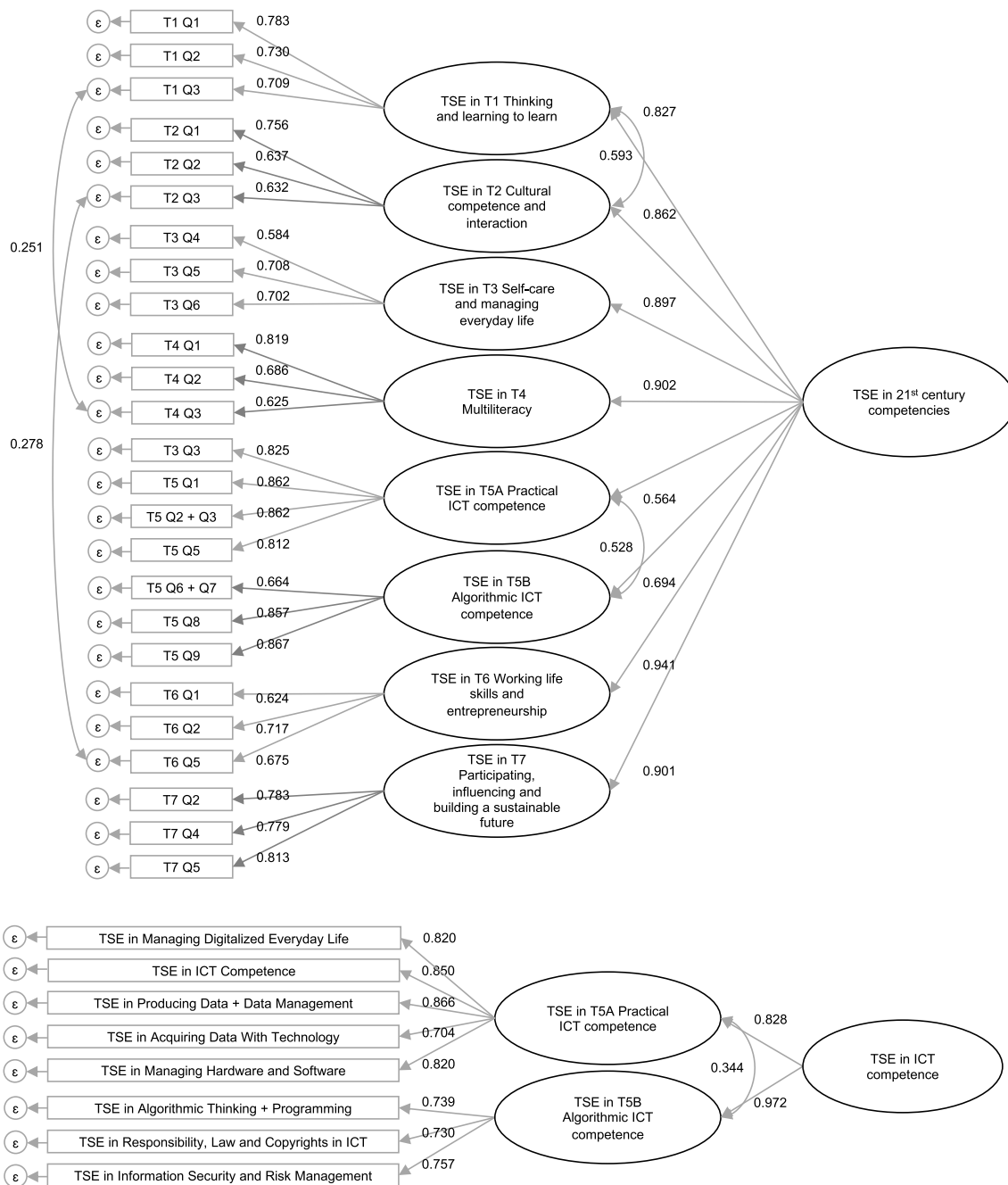


Fig. 1. The confirmed second order eight-factor model of teaching self-efficacy (TSE) in the seven Finnish transversal competencies (corresponding to the “Modified” model in Table 2) as well as the second order two-factor model of TSE in ICT competencies (the “Two ICT” model in Table 2) with item-level factor loadings. For the item contents, see Table 1.

SE in the two different ICT competencies as well as other 21st century competencies by age, gender, as well as subject matter and faculty backgrounds (i.e., science, engineering, technology and mathematics, STEM vs. social-, humanistic, and education sciences, SHAPE), we estimated main effects and conducted moderated linear regression analyses by means of three-way-interaction product terms, controlling for faculty. The analyses were conducted with R statistical software (version 4.1.3, RStudio version 2022.07.1; Baldwin et al., 2010) and the complementary packages: lavaan (Rosseel, 2012), EFAtools (Steiner & Grieder, 2020), ggeffects (Lüdtke, 2018), and tidyverse (Wickham et al., 2019). The descriptive statistics were acquired using IBM SPSS Statistics version 29.0.1.0.

3.2. Results

As further support on construct validity, CFAs revealed good fit for teaching self-efficacy ($\chi^2(87) = 159.864$, $p < 0.001$, $scf = 1.184$, $CFI = 0.959$, $RMSEA = 0.055$ [0.041, 0.068], $SRMR = 0.046$), self-efficacy ($\chi^2(87) = 141.817$, $p < 0.001$, $scf = 1.181$, $CFI = 0.967$, $RMSEA = 0.047$ [0.032, 0.061], $SRMR = 0.045$) and schooling ($\chi^2(87) = 150.831$, $p < 0.001$, $scf = 1.271$, $CFI = 0.969$, $RMSEA = 0.047$ [0.038, 0.067], $SRMR = 0.042$). Also, the McDonald’s Omegas (Table 4) indicated sufficient internal consistency of the measures. As expected, the correlations of SE and TSE were around 0.950 for the ICT competencies and 0.861 for the other 21st century competencies. Regarding the correlations of age to TSE and SE, only the small positive correlation between age and TSE in

Table 3

Descriptive statistics and correlations of the latent variables in Study 1.

Teaching self-efficacy in	ω	M	Med	SD	Corr.								
					T1	T2	T3	T4	T5a	T5b	T6	T7	
T1 Thinking and Learning to Learn	0.893	3.84	4.00	0.92									
T2 Cultural Competence, Interaction and Self-Expression	0.867	4.00	4.00	1.00	0.668 ^a								
T3 Self-Care and Managing Everyday Life	0.705	3.84	4.00	0.89	0.525 ^a	0.532 ^a							
T4 Multiliteracy	0.756	3.77	3.67	0.98	0.668 ^a	0.594 ^a	0.583 ^a						
T5a Practical ICT	0.922	3.54	3.50	1.03	0.418 ^a	0.401 ^a	0.434 ^a	0.538 ^a					
T5b Algorithmic ICT	0.840	2.63	2.50	1.07	0.393 ^a	0.380 ^a	0.534 ^a	0.487 ^a	0.655 ^a				
T6 Working Life Skills and Entrepreneurship	0.712	4.02	4.00	0.95	0.615 ^a	0.633 ^a	0.572 ^a	0.588 ^a	0.432 ^a	0.437 ^a			
T7 Participating, Influencing and Building a Sustainable Future	0.834	3.82	4.00	1.06	0.586 ^a	0.573 ^a	0.626 ^a	0.625 ^a	0.403 ^a	0.532 ^a	0.679 ^a		
2nd order 21st century skills	0.962	3.68	3.65	0.76	0.781 ^a	0.770 ^a	0.770 ^a	0.821 ^a	0.702 ^a	0.726 ^a	0.799 ^a	0.815 ^a	

Notes: Likert -scale 1–6.

^a Correlation is significant at the .01 level (2-tailed).**Table 4**

Descriptive statistics of Study 2.

Dimension	ω	M	Med	SD									
					1	2	3	4	5	6	7	8	9
Practical ICT													
1 TSE	0.900	3.94	4.00	1.00	1								
2 Self-efficacy	0.895	4.05	4.00	1.00	0.951 ^a	1							
3 Schooling	0.918	3.37	3.50	1.19	0.515 ^a	0.533 ^a	1						
Algorithmic ICT													
4 TSE	0.695	3.01	3.00	0.97	0.676 ^a	0.639 ^a	0.380 ^a	1					
5 Self-efficacy	0.727	3.06	3.00	0.98	0.666 ^a	0.672 ^a	0.406 ^a	0.949 ^a	1				
6 Schooling	0.786	2.55	2.50	1.01	0.413 ^a	0.415 ^a	0.770 ^a	0.612 ^a	0.638 ^a	1			
Other 21st cent. skills													
7 TSE	0.791	4.33	4.33	0.71	0.425 ^a	0.373 ^a	0.101	0.433 ^a	0.371 ^a	0.154 ^a	1		
8 Self-efficacy	0.754	4.40	4.50	0.69	0.427 ^a	0.430 ^a	0.152 ^a	0.432 ^a	0.430 ^a	0.194 ^a	0.861 ^a	1	
9 Schooling	0.802	3.82	3.83	0.88	0.235 ^a	0.238 ^a	0.615 ^a	0.264 ^a	0.301 ^a	0.561 ^a	0.353 ^a	0.403 ^a	1
Age	NA	27	24	8.3	−0.013	−0.046	−0.393 ^b	0.007	−0.031	−0.300 ^a	0.115 ^b	0.090	−0.303 ^a

Notes: Likert -scale 1–6.

^a Correlation is significant at the .01 level (2-tailed).^b Correlation is significant at the .05 level (2-tailed).

other 21st century competencies was statistically significant. The correlations between age and schooling were moderately negative (−0.393 to −0.300) and statistically significant in all the three competencies with the strongest negative correlation between age and schooling in practical ICT competence.

The descriptive statistics (Table 4) indicated that regarding the ICT competencies in general, the teacher students experienced less TSE and SE than in the other 21st century competencies. The algorithmic competencies were at the bottom end of the stack regarding both SE and TSE. Also, the participants' experiences of having learned the competencies

Table 5

Single unadjusted regression estimates of self-efficacy (SE) and teaching self-efficacy (TSE) in the ICT and other 21st century competencies.

Dependent Predictor	β	SE Practical SE	p	R ²	β	SE Algorithmic SE	p	R ²	β	SE Other 21st century competencies SE	p	R ²
Age: 18–21	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Age: 21–31	0.154	0.127	0.23		0.129	0.109	0.237		0.103	0.055	0.06	
Age: 31–62	−0.136	0.14	0.35	0.01	−0.126	0.124	0.310	0.01	0.090	0.063	0.15	0.01
Gender: F	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Gender: M	0.446	0.152	<0.05	0.03	0.375	0.130	<0.05	0.03	−0.007	0.067	0.92	0.00
Schooling	0.501	0.044	<0.001	0.28	0.422	0.037	<0.001	0.28	0.234	0.029	<0.001	0.16
Faculty: STEM	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Faculty: SHAPE	−0.727	0.238	<0.05	0.03	−0.726	0.203	<0.001	0.04	−0.219	0.105	<0.05	0.01

Dependent Predictor	β	TSE Practical SE	p	R ²	β	TSE Algorithmic SE	p	R ²	β	TSE Other 21st century competencies SE	p	R ²
Age: 18–21	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Age: 21–31	0.279	0.123	<0.05		0.246	0.102	<0.05		0.251	0.069	<0.001	
Age: 31–62	−0.014	0.141	0.92	0.02	0.004	0.116	0.97		0.188	0.079	<0.05	0.04
Gender: F	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Gender: M	0.511	0.147	<0.001	0.04	0.413	0.122	<0.001	0.03	0.044	0.085	0.604	0.00
Schooling	0.471	0.044	<0.001	0.25	0.370	0.035	<0.001	0.25	0.260	0.038	<0.001	0.12
Faculty: STEM	ref.	ref.	ref.		ref.	ref.	ref.		ref.	ref.	ref.	
Faculty: SHAPE	−0.867	0.230	<0.001	0.04	−0.783	0.189	<0.001	0.05	−0.310	0.132	<0.05	0.02

already at school (i.e., schooling) were less frequent for the ICT competencies, especially the algorithmic competencies.

Among the single regression estimates (Table 5), the relation of schooling to the competencies overall turned out to be the strongest, explaining twice the amount of variance ($\approx 25\%$) of the self-efficacies in the ICT competencies as compared to other 21st century competencies. Background STEM-faculty was also in significant relation to self-efficacies in all of the measured competencies (although the differences regarding the other competencies were not significant in an independent samples *t*-test; SE: $t(322) = 1.518$, $p = 0.13$; TSE: $t(322) = 1.549$, $p = 0.12$). Unlike regarding the other competencies, male gender was in a significant relation to TSE and SE in the ICT competencies. Higher age was in a significant relation to TSE in the other competencies and the more mature teacher students felt generally more competent guiding their pupils in the non-digital 21st century competencies. The age group 21–31 also felt significantly more competent in teaching all

the ICT competencies.

Regarding the interaction models (controlling for faculty, Table 6, Fig. 2), the interaction between schooling and age was significant regarding the self-efficacies in the ICT competencies, and thus having learned the competencies in school translated to better self-efficacies in the younger age groups compared to the older. A milder effect was visible regarding the other 21st century competencies. The interaction between schooling and gender was not significant regarding SE in the practical ICT competence but was so regarding SE in the algorithmic competence. This indicates that among females, learning algorithmic skills in school was more positively related with their self-efficacy, whereas schooling history among males did not have a very strong role for their self-efficacy. The interaction between gender and age was also significant regarding self-efficacies in both ICT competencies but not the other 21st century competencies, with lower age in conjunction with male gender being associated with better self-efficacies in the ICT

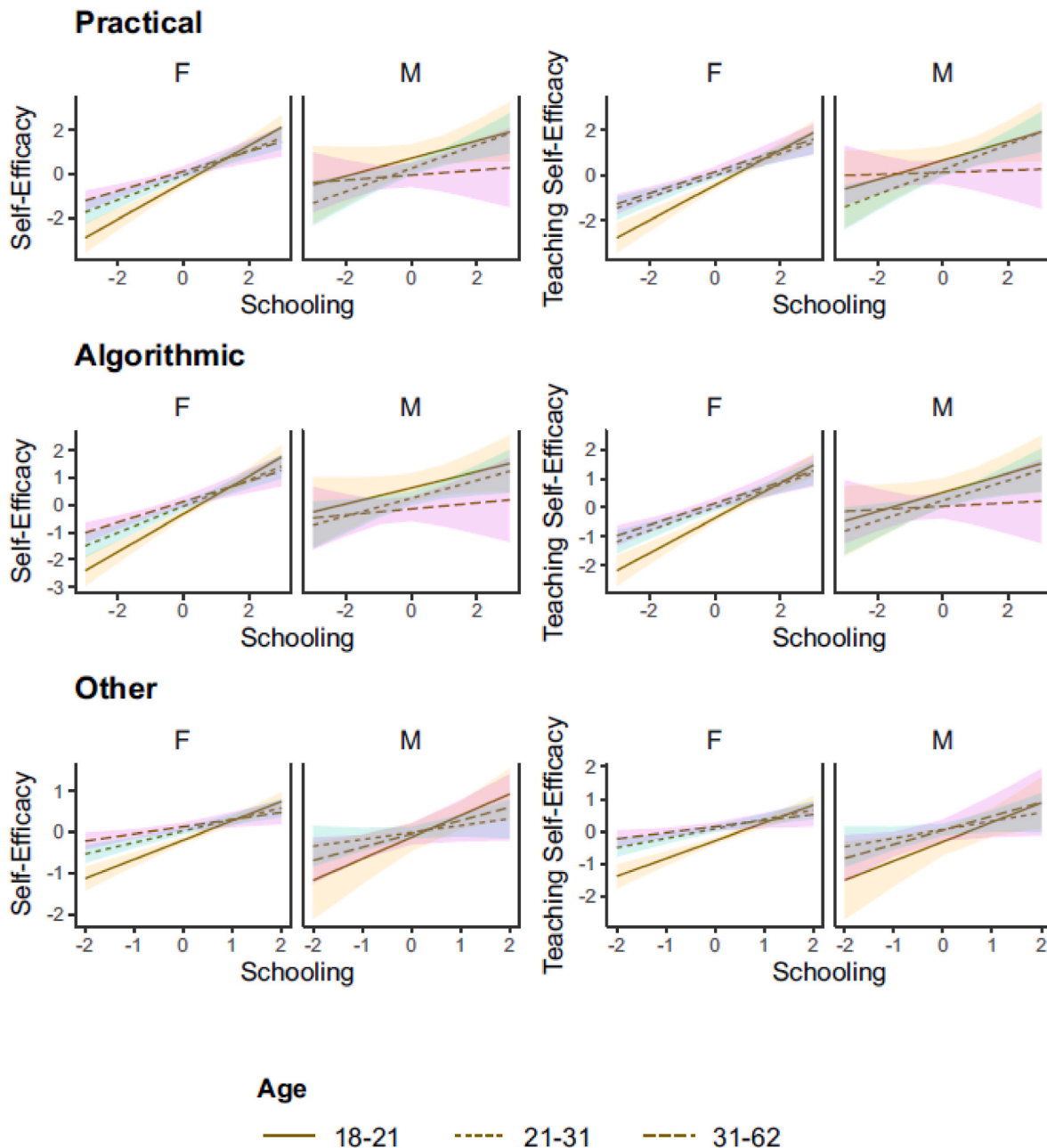


Fig. 2. Marginal effects of three-way-interaction models by gender, age, and previous schooling on practical and algorithmic ICT-skills, as well as other transversal competencies (see Table 6). Note: Confidence intervals (95 %) are shaded for each age group.

Table 6

Moderated linear regression models of TSE and SE in the three 21st century competence categories with three-way-interaction product terms by age, gender, and schooling. Faculty controlled (i.e., STEM vs. social-, education-, and humanistic sciences, i.e., SHAPE).

Dependent Predictor	SE Practical			SE Algorithmic			SE Other 21st century competencies		
	B	SE	p	B	SE	p	B	SE	p
Intercept	0.094	0.218	0.67	0.192	0.185	0.30	−0.036	0.102	0.73
Schooling	0.831	0.098	<0.001	0.690	0.08	<0.001	0.467	0.061	<0.001
Gender: M	1.088	0.332	<0.01	0.954	0.275	<0.001	0.067	0.171	0.69
Age: 21–31	0.334	0.120	<0.01	0.284	0.102	<0.01	0.219	0.056	<0.001
Age: 31–62	0.510	0.144	<0.001	0.449	0.122	<0.001	0.321	0.065	<0.001
Faculty: SHAPE	−0.510	0.202	<0.05	−0.553	0.171	<0.01	−0.169	0.094	0.07
Schooling x Gender: M	−0.433	0.260	0.10	−0.396	0.193	<0.05	0.057	0.193	0.77
Schooling x Age: 21–31	−0.272	0.128	<0.05	−0.209	0.105	<0.05	−0.190	0.081	<0.05
Schooling x Age: 31–62	−0.388	0.133	<0.01	−0.313	0.109	<0.01	−0.295	0.084	<0.001
Gender: M x Age: 21–31	−0.779	0.373	<0.05	−0.662	0.311	<0.05	−0.104	0.188	0.58
Gender: M x Age: 31–62	−1.262	0.443	<0.01	−1.221	0.3713	<0.01	−0.241	0.221	0.28
Schooling x Gender: M x Age: 21–31	0.401	0.313	0.202	0.242	0.244	0.32	−0.17	0.231	0.46
Schooling x Gender: M x Age: 21–31 x Age: 31–62	0.102	0.375	0.786	0.129	0.300	0.67	0.093	0.26	0.72
Model fit	F (12, 303) = 15.77, p < .001, R ² Adj. = 0.36			F (12, 303) = 16.59, p < .001, R ² Adj. = 0.37			F (12,303) = 10.37, p < .001, R ² Adj. = 0.26		
Dependent Predictor	TSE Practical			TSE Algorithmic			TSE Other 21st century competencies		
	B	SE	p	B	SE	p	B	SE	p
Intercept	0.155	0.212	0.47	0.187	0.175	0.29	−0.093	0.131	0.48
Schooling	0.773	0.095	<0.001	0.606	0.076	<0.001	0.551	0.079	<0.001
Gender: M	1.091	0.323	<0.001	0.885	0.261	<0.001	−0.027	0.219	0.90
Age: 21–31	0.429	0.116	<0.001	0.367	0.096	<0.001	0.366	0.072	<0.001
Age: 31–62	0.595	0.140	<0.001	0.507	0.116	<0.001	0.434	0.083	<0.001
Faculty: SHAPE	−0.620	0.196	<0.01	−0.583	0.162	<0.001	−0.207	0.121	0.09
Schooling x Gender: M	−0.354	0.253	0.16	−0.277	0.183	0.131	0.047	0.247	0.85
Schooling x Age: 21–31	−0.292	0.125	<0.05	−0.210	0.099	<0.05	−0.261	0.103	<0.05
Schooling x Age: 31–62	−0.296	0.130	<0.05	−0.235	0.103	<0.05	−0.365	0.108	<0.001
Gender: M x Age: 21–31	−0.828	0.363	<0.05	−0.649	0.294	<0.05	0.003	0.241	0.99
Gender: M x Age: 31–62	−1.115	0.431	<0.05	−0.988	0.352	<0.05	−0.084	0.283	0.766
Schooling x Gender: M x Age: 21–31	0.424	0.305	0.17	0.231	0.231	0.32	−0.075	0.297	0.801
Schooling x Gender: M x Age: 21–31 x Age: 31–62	−0.078	0.365	0.832	−0.036	0.284	0.10	0.20	0.333	0.55
Model fit	F (12, 303) = 15.86, p < .001, R ² Adj. = 0.36			F (12,303) = 15.61, p < .001, R ² Adj. = 0.35			F (12,303) = 9.12, p < .001, R ² Adj. = 0.24		

Notes: The reference category for *gender* was female, for *age* 18–21, and for *Faculty* STEM.

competencies. None of the three-way interactions were significant.

4. Discussion

It is most urgent that teachers can equally support all their pupils in the development of vital algorithmic and ICT competencies of the 21st century (Harari, 2023; Messner et al., 2019; Ntiri, 2009). It has been noted that our teacher students seem to lack self-efficacy especially in supporting their pupils' ICT competencies (Ranta et al., 2022). However, the depiction of these competencies in the Finnish curricula lack nuance, as it is a very different skill to use humanely hyper-intuitive user interface designs in daily life as compared to the understanding of all their layering and functioning logic on the level of the algorithm, as well as the almost infinite, creative, yet highly abstract possibilities of computer programming. Indeed, this study confirmed two separate dimensions of ICT competencies within an eight-factor structure of 21st century competence as fitting future Finnish teachers' views of the curricular 21st century competencies, further revealing their low self-efficacy in (teaching) the ICT competencies, especially on the algorithmic level, as well as certain biases related to age, gender, and former schooling.

The first ICT competence dimension, *practical ICT competence*, is characterized by an instrumental, learning-oriented focus and seeing ICTs as tools in the learning process as well as a part of the learning environment. It is roughly comparable to the basic level competence in earlier studies (e.g., Fraillon et al., 2014; Rohatgi et al., 2016; Tømte & Hatlevik, 2011). In the Finnish curricula, this type of dimension is very much highlighted also in sections regarding, e.g., the school's operational culture and learning environments (FNAE, 2014).

The *algorithmic ICT competence*, on the other hand, is conceptually related to the more computational dimensions in the field of computer science and requires delving deeper into the functioning logic of technologies, thus including their more abstract, computational aspects (i.e., algorithms and programming; Brennan & Resnick, 2012; Wing, 2006) as well as understanding the digital realm from the point of view of information security, privacy, and copyright. We chose to use the term "*algorithmic*" in order to refer to this fundamentally different kind of knowledge in relation to the practical, more procedural knowledge on ICT. We see this roughly equivalent to a deeper level technological knowledge or content knowledge related to technology in Koehler and Mishra's (2009) framework, and the advanced competencies described in some earlier studies (e.g., Fraillon et al., 2014). It is of note that, especially for younger children, the more theoretical algorithmic competencies can also be developed unplugged, as many practical, everyday processes can be represented as algorithms through play (e.g., Kruskopf et al., 2019; 2021b). All in all, according to the National Curricula for Basic Education (FNAE, 2014), the practical ICT competence would seem to cover ICTs as "*tools*" aiding in the learning process, whereas the algorithmic competencies help delve deeper into the realm of ICT as "*an object of learning itself*" (FNAE, 2014). The algorithmic competencies are central to the understanding of the functioning logic of the socio-digital algorithms governing our societies, i.e., the Xs, Facebooks and TikToks powerfully shaping our view of the world (in what is sometimes labeled as the "post-truth" era; McIntyre, 2018). This is why, in the name of equity, such skills should not be neglected in school teaching, and also why it is alarming that our teacher students seemed to lack self-efficacy in teaching this particular competence.

Teacher students' expectancy of success in the (teaching of) ICT competencies might be based on their prior experiences on their own past school careers (i.e., their background, cultural milieu, and previous achievement-related experiences; Eccles & Wigfield, 2020). In fact, we found that the teacher students' experiences of having learned the competencies during their own school careers were less frequent regarding the ICT competencies in comparison with the other curricular 21st century competencies, and the rarest of all regarding the algorithmic competencies. Consequently, it is understandable that also the

self-efficacies were, similarly, on a generally lower level regarding the ICT competencies in both our samples. The correlations between age and previous schooling were, expectedly, significant, and moderately negative regarding all of the 21st century competencies, with the strongest negative correlation (almost -0.400) between age and practical ICT competence, indicating the increasing role of these competencies in the curricula over time.

Interestingly, an opposite phenomenon regarding age was visible in the non-digital 21st century competencies, with age linearly increasing both the experienced competence and teaching self-efficacy. Perhaps self-efficacy in the other competencies combined represents a sort of wisdom increasing with age and life experience, whereas the ICT competencies are very different, or novel in nature, in this respect. Considering the fact that, after controlling for confounders in the interaction models, the oldest age group fared the worst, in their opinion, in the (teaching of) ICT competencies, these results seem to support the so-called "digital native" -metaphor (e.g., Hietajärvi, 2019; Prensky, 2001) regarding the ICT competencies.

Considering gender, this study highlighted alarming inequalities still visible among teacher students today. Male gender was a significant single predictor of SE and TSE in both practical and algorithmic ICT competencies, explaining 3–4 % of their variance. This effect was not visible regarding the other 21st century competencies. Younger age in conjunction with male gender also led to significantly better self-efficacies in the ICT competencies in this sample. Gender was also a significant moderator of the relation of school-related learning of the algorithmic competence to self-efficacy, and females felt better at utilizing school-based learning of the code. Regarding the practical ICT competence, this interaction effect was not visible. Thus, gender differences in the students' self-efficacy in practical ICT competence, concerning the learning environment, operational culture and other general parts of the national curricula (FNAE, 2014), may root in factors outside school, as may males' self-efficacy in the algorithmic competence.

One would thus need to look outside school to find the source of the discovered gender imbalance in ICT self-efficacy, such as task value beliefs (i.e., interest, utility and cost; Eccles & Parsons, 2020; Hidi et al., 2004), differences in recreational use habits, general comfort level or anxiety related to learning ICT as well as attributional factors (Rohatgi et al., 2016; Torkzadeh et al., 2006; Tømte & Hatlevik, 2011; Wilson & Shrock, 2001). Perhaps the boys' evidently strong digital engagement outside school (e.g., gaming; Hietajärvi et al., 2015; Hietajärvi et al., 2019; Kruskopf, Hakkarainen, et al., 2021) provides transfer, and their personal interest and enjoyment (Fraillon et al., 2014) the motivation, in this respect, to the learning of both practical and algorithmic ICT competencies. Nevertheless, the result is interesting considering the fact that Finnish boys' reading performance in school in general has been declining in recent years (e.g., reading: Torppa et al., 2018).

Alternatively, despite extensive public counteracting efforts, gender imbalances can, to an extent, still lie on the level of the hidden curriculum (Giroux & Penna, 1979). As Shapiro and Williams (2012) have already argued regarding STEM-fields in general, implicit sociocultural stereotype threats might undermine female self-efficacy and interest also in ICT careers: If the students do not think, or believe, they can pursue a career in technology and engineering (among mathematics and science), they will not have an interest in pursuing it (Eccles & Wigfield, 2020; Lakanen & Kärkkäinen, 2019; Lent et al., 2005; Shapiro & Williams, 2012). In fact, Finland has indeed been found to suffer from high levels of gender based occupational and educational segregation by European standards (Burchell et al., 2014). We need to find new ways to support boys' interest in reading and girls' interest in the algorithmic realm.

As a potential cause or consequence of the gender imbalance, Lishinski et al. (2016) documented an interesting gender difference in the programming self-efficacy feedback loop during an introductory course: The females tended to adjust their initial self-efficacy beliefs more

strongly to negative feedback, even though the final course grades indicated equal performance. This might lead them to disengage through internalizing the errors as personal failures, thus creating negative mastery experiences (Kinnunen & Simon, 2010), although the manifestation of errors is a necessary part of actual coding practice (i.e., debugging). This kind of a mechanism would naturally explain why girls might shy away from selective coding courses.

Nevertheless, as algorithms are an increasingly important basis of our societal life through the thoroughly pervasive media technologies in almost each of their pockets or purses and also because young girls seem to be especially prone to the negative effects of social media algorithms (Beyens et al., 2016; Castrén et al., 2022; Kelly et al., 2018; Waterson & Milmo, 2021), it is essential that they gain the necessary literacy to prevent falling involuntary victims of the algorithms in their lives. It is indisputable that the bridging of the gender equality gap regarding self-efficacy in the 21st century ICT competencies requires formal educational interventions on the pre- and in-service levels of teacher education in order to, ultimately, prevent the transfer of this kind of ICT stereotype threat to our future generations (Kaarakainen et al., 2018; Lishinski et al., 2016; Shapiro et al., 2013).

As formal schooling ended up explaining such a significant portion of the variance of self-efficacies in the ICT competencies and considering the fact that the algorithmic issues are allocated, in part, to the teachers of mathematical sciences in the curricula (FNAE, 2014), we sought to confirm whether the (subject matter) teacher students' originating faculty at the university predicted TSE and SE in these 21st century competencies. Indeed, we found that studying in the faculties of mathematical or natural sciences was in a significant relation to self-efficacy and teaching self-efficacy in the practical and algorithmic competencies.

Considering the discovered tight connection between ICT competencies and formal schooling, some earlier accounts that school related ICT use is *not* associated with ICT self-efficacy (Askar & Davenport, 2009; Rohatgi et al., 2016; Tømte & Hatlevik, 2011) might be explained by the comprehensive introduction of these technologies to schools, as well as universities, only later on. This is supported also by the fact that in this sample, younger age groups were better able to translate school-related learning of the ICT competencies to (teaching) self-efficacy, whereas regarding other 21st century competencies this effect was more subtle.

On the other hand, although certain objectives of programming and algorithmic thinking are allocated to mathematics teachers in the curricula, for example, the modern Finnish school requires all teachers to instruct the pupils in also their computational thinking and literacy (FNAE, 2014), and, not least importantly, regarding information security and copyrights (Hooft Graafland, 2018). In fact, Prat et al. (2020) found the factors that best explained differences in ability to learn the coding language Python were working memory (34% of variance) and language aptitude (17% of variance), when surprisingly numeracy explained only 2% of variance, indicating languages might be even more central to learning the "language of the code" than mathematics. And as the learning of language requires extensive formal education (slightly variant depending on the language in question), based on our results, so does coding.

4.1. Methodological aspects and implications for future research

This study supports earlier accounts on at least two different dimensions of 21st century ICT competencies. Benefits of the setting as compared to earlier research include examination of multiple dimensions of ICT competencies (including algorithmic thinking) in one study as well as contrasting ICT competencies to the other 21st century competencies. Where the ICILS studies (e.g., Fraillon et al., 2014; Rohatgi et al., 2016), for example, investigate teachers as sources of ICT competencies as perceived by their pupils, this study looks closer into the self-efficacy of future teachers themselves. Regarding the discovered

gender imbalances, this study was able to provide new insights regarding the future teachers' self-efficacy in instructing their pupils in these competencies, not just their personal technological self-efficacy.

4.1.1. Limitations

Despite the significant contributions of this study there are several limitations that need to be considered. As the study applies to the pre-service context, further studies, especially regarding the effects of age and schooling, might benefit from including data from the in-service population of teachers, as computer self-efficacy plays an even more important role for teachers of higher age in the context of emphasizing ICT competencies in classrooms (Siddiq & Scherer, 2016). In addition, the inclusion of more extensive background variables regarding the teachers' experienced task value (i.e., interest, utility and cost), affective aspects and metacognitions as well as the informal contexts of ICT learning might provide complementary insights regarding the two dimensions of ICT competencies within the classical expectancy-value framework (Eccles-Parsons et al., 1983).

In addition to (teaching) self-efficacy, other central factors influencing expectancy beliefs might be the general optimism or mindset regarding success (Dweck, 2016) as well as causal attributions (Weiner, 1979). Neither was socioeconomic background addressed in the present study (Claro et al., 2015; Vekiri, 2010). Including these variables in further studies on ICT competencies might enable a broadened perspective. Furthermore, our convenience samples, recruited from a large introductory course of educational psychology, may have been influenced by the individual teacher students' personal motivational factors towards modern topics in teacher education due to the voluntary nature of the survey.

The imbalanced gender distribution of the two studies roughly corresponds to the gender distribution of university students in educational fields on a global level (OECD, 2021). Reasons for this, such as economic development, the position of women in society or cultural definitions of masculinity may play their role here (e.g., Drudy, 2008). In Finland, there is a female dominance also at the university level in general (56 %; Statistics Finland, 2021). Some of the significant results are based on the sample of male subject teacher students originating in the STEM-faculties, who were sparse in number ($n = 19$). Due to the imbalanced gender distribution in teacher education (Drudy, 2008; OECD, 2021; Statistics Finland, 2021), this challenge is concurrently hard to overcome: Even with the male-dominant gender distribution of the faculties of natural sciences (Statistics Finland, 2021), the majority of students applying to teacher education from these faculties are female. Thus, despite the significant result in the intersection of faculty and gender, we suggest some caution regarding generalization. Our sample was also not large enough to make reliable inference outside the binary genders, so including larger samples in future investigations might be able to overcome also this limitation and reveal important insights regarding the self-efficacies of gender minorities, as well.

4.2. Conclusions

The world around us is changing conspicuously due to digital technologies, and our teachers should prepare our new generations to live in their highly unexpected future environments (Messner et al., 2019). As of this moment, AI technologies are developing at an exponentially rapid pace. These may fundamentally challenge also current educational practices. Naturally, more and more creative human labor is becoming automated through AI, even including computer programming itself (Perkel, 2023), which is why one might ask whether these deeper algorithmic competencies are really something our future citizens might need in their future society, after all. Well, in response there might be analogies made to certain other curricular entities, which are already highly automated, but which we still consider essential general understanding achieved in basic education, such as, e.g., certain mathematical concepts and formulae while there are efficient calculators widely

available through our everyday digital tools. Another analogy is literacy itself, with voiceover AI technologies and audio books gaining increasing ground. We argue that algorithmic phenomena are just as important to highlight equally to all pupils, as they have not yet achieved as rigid a grounding in basic education as in forming the basis of even our democracy and culture itself: The development of the pupils' entire thinking is mediated by pervasive social media technologies, games and digital marketing (Harari, 2023; Kruskopf, Hakkarainen, et al., 2021; Martins et al., 2019; Messner et al., 2019; Moisala et al., 2017). In addition, digital literacy is an essential part of the other important future skills, such as tools for reading, learning, thinking, and working in the 21st century. Sometimes learning these basic, critical skills is *hard* and requires one to put down immediate rewards: School should be the place where this is possible for all pupils, with the teachers' support.

Supporting the pupils requires also the teachers' personal and teaching self-efficacy in the required practical and algorithmic ICT competencies. This study provides interesting insights regarding future teachers' readiness to teach ICT competencies, which currently appear a clear pitfall among other essential 21st century competencies in the Finnish context (Ranta et al., 2022). In order to achieve an active, fully literate citizenship in our modern socio-digital ecology, an algorithmic understanding of the pervasive, digital interfaces around us is required. Based on our results, teachers need more support in the development of not only their everyday digital interactions but also in this algorithmic understanding that still seems to be a rare, gender-biased competence among these Finnish teacher students. If the school is to prepare our pupils to actually achieve a "*digitally sustainable future*" (FNAE, 2014; Messner et al., 2019), it is essential, first of all, that future teachers themselves acquire the necessary ICT competencies already during their own school paths as well as through comprehensive interventions during their teacher education (Israel et al., 2015). It is not enough that they only utilize ICT as a practical *tool for learning*, but there is a clear need to also systematically cover it as an *object of learning* itself, on a more theoretical level that reaches beyond our daily, surface-level user interfaces (FNAE, 2014; Koehler & Mishra, 2009). Both of these aspects are highly necessary in order to achieve the basic, broad-based literacy required in our 21st century digitalized society (Ntiri, 2009), and should thus be taken into account by adding relevant modules at schools as well as pre-, in-service and continuing teacher education. These are the basic skills that all citizens need increasingly in their everyday environments (e.g., in navigating social media), which is also why it is important to engage students, promote interest and apply guided inquiry-based practices such as phenomenon-based learning (Lonka, 2018). By using approaches that put matters in a meaningful context, it is possible to enable the intrinsic motivation towards learning the more theoretical concepts on the algorithmic level.

Ethical declaration

This pseudonymized study is based on the written, thoroughly informed consent of subjects who are over 18 years of age and to whom the research design poses no harms or threats. The Finnish National Board on Research Integrity has stated that no formal ethical approval is required for research that adheres to the tenets of the Helsinki Declaration, as this study does.

CRedit authorship contribution statement

Milla Kruskopf: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Rekar Abdulhamed:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis. **Mette Ranta:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Heidi Lammasaari: Writing – original draft, Project administration, Funding acquisition, Data curation. **Kirsti Lonka:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Curre (curre.helsinki.fi) in order to help copyedit and shorten the abstract and highlights of the study. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors have no competing interests to declare regarding this research.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tate.2024.104574>.

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