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Robbert Smit, Clemens Waibel & Rahel Schmid

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Assisting in a computer science education centre as a field-based internship for pre-service teachers

Robbert Smit, Clemens Waibel and Rahel Schmid

Science Education St.Gallen University of Teacher Education, St.Gallen, Switzerland

ABSTRACT

Background and Context: To offer more experiences in the field, our study employed secondary school pre-service teachers as assistants in courses for secondary school students learning computer coding with the help of smart textiles.
Objective: Did pre-service teachers assisting in CS courses have more highly developed pedagogical content knowledge (PCK) and more positive attitudes toward computer science teaching than a control group.
Method: We administered a teacher questionnaire ($N = 47$) with items related to pre-service teachers' awareness of CS and attitudes toward CS learning environments. Data on emotional experiences were collected.
Findings: Two moderate effects helped to explain variances between the groups on measures of belief in effectiveness of CS learning and peer support over time. Their positive experiences were confirmed by their decline in negative emotions.
Implications: The results of our research might help to expand our not yet very broad knowledge of meaningful educational experiences for pre-service teachers' CS education.

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Pre-service teachers; computer science; emotional experiences; coding skills

Introduction

Experience in the field is a major factor in teacher education worldwide (Darling-Hammond, 2017). An internship in a school provides pre-service teachers the opportunity to transfer the knowledge of computer science (CS) they gain during their higher education and apply it to their teaching practice.

The quality of a mentor teacher in an internship is a crucial factor for the pre-service teacher's learning success; a mentor should, for example, be able to model effective teaching and make connections between theory and practice (Ellis et al., 2020). For CS specifically, this means that if the mentor teacher is not a positive model, the pre-service teacher is not likely to develop strong self-efficacy beliefs and might even be discouraged from using CS in future teaching activities (Bullock, 2004; Yeşilyurt et al., 2016). Lack of self-efficacy beliefs is a major obstacle to the implementation of effective information and communication technology (ICT) in schools (Elstad & Christophersen, 2017; Han et al.,

CONTACT Robbert Smit robbert.smit@phsg.ch St. Gallen University of Teacher Education, Notkerstr. 27, St. Gallen 9000, Switzerland

2017), whereas positive emotions are significantly related to pre-service teachers' use of ICT in the field (Kay, 2007; Kim & Jang, 2015). The discussion of the missing practice models is now briefly interrupted here to clarify terms and the specific situation in the country where the study took place.

ICT stands for information and communication technologies and are defined, for the purposes of this article, as a diverse set of technological tools and resources used to communicate and to create, disseminate, store and manage information. It can include computer networks, communications, internet access, hardware, software, and cloud computing. We consider CS as foundational part of ICT. It involves "the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society" (Tucker, 2003, p. 6).

In Switzerland, where our study was conducted, the traditional name of the school's subject has been Media and ICT. In the new Swiss-German curriculum 21, the C has been deleted from ICT and the subject is now referred to as Media and Informatics (Döbeli Honegger & Merz, 2015). Informatics as a subject's content in Swiss schools translates well as computer science. To be allowed to teach the subject of media and CS at the secondary school level (grades 7–9 or ages 13–15), student teachers must acquire competencies in both areas – media and CS. This study focuses on competencies in the field of CS; therefore, we will only refer to CS (not media).

In Switzerland, secondary pre-service teachers are required to undertake shorter and longer internships throughout their four years of study, with the assumption of increased task demands over the training period. However, these internships usually involve different subjects and, depending on the grade level, there might not be a specific computer science lesson at all. In addition, topics on media and computer science must be covered both. CS has been integrated into other subjects in the curriculum as a cross-curricular competence. This makes it clear that the opportunities for practical experience with CS in the internships are rather limited and more complex compared to other subjects. During the internship, the pre-service teacher is supervised by a mentor teaching in the classroom. In addition, a supervisor from the university visits once during each internship.

Unfortunately, Switzerland, Germany, and the United States do not yet have sufficient numbers of experienced CS teachers who can serve as effective models for the integration of CS in lessons (Bergner, 2021; Döbeli Honegger et al., 2019; Pollock et al., 2015). Our research investigated a solution to this problem. In our region, a new centre for teacher and student CS education has recently opened. Its format is unique because it is embedded in an incubator for start-up enterprises in the technology field. The centre is a network of various universities and institutions with the aim of familiarising young people with digital skills. Teachers and school students can experience the real world of technology while they learn to apply their acquired CS skills in an authentic science and technology environment. To enhance the learning of school students and practitioners, we employed pre-service teachers as assistants for teaching CS at the secondary school level. This project was intended to benefit these volunteer pre-service teachers, helping them to gain knowledge and skills through the opportunity to use CS in an authentic learning environment, and at the same time, learn about a pedagogical model that would promote effective learning. In other words, the pre-service teachers would have the experience of applying pedagogical content knowledge (PCK) of CS in their teaching practice. Thus, instead of going into schools for their CS-internship – which are not yet available in sufficient quantity and quality (Bergner, 2021; Mouza et al., 2022), pre-service teachers were able to assist course instructors with the delivery of coding courses to classes. Their task was to support secondary school students during the problem-solving sequences of design tasks, which is one of the most difficult issues encountered by pre-service teachers during their internships (Pollock et al., 2015). Problem solving with the help of computer coding is also a major digital competency that Swiss school students need to master (Deutschschweizer Erziehungsdirektoren-Konferenz D-EDK, 2016).

In the course provided by the technology centre, the secondary school students worked on exercises requiring the use of a micro:bit in order to program a LED-fabric matrix. The combination of smart textiles and programming workshops has been shown to provide a successful environment for fostering the confidence and CS problem-solving skills of secondary school students (Katterfeldt et al., 2009; Nugent et al., 2019; Schmid et al., 2022). This design was a completely new approach to stimulating and promoting digital transformation in schools providing basic education in Switzerland. However, it must be borne in mind that there was no current evidence supporting its success. Therefore, it was important to explore and report the effects of our project on teacher education. We hypothesised that the experience of assisting course instructors and helping secondary school students in a course would strengthen pre-service teachers' self-efficacy beliefs, eliminate any negative emotions they might have, and develop their PCK for teaching CS.

Theoretical framework

CS teacher education and problems in training

The routine training of CS teachers in compulsory education is still in its infancy (Sadik et al., 2020). The preparation of CS teachers varies widely between countries, ranging from short-term professional development workshops to full degree programmes (Yadav et al., 2022). As evidence of problems among new CS teachers grows, so does a greater need for research that addresses their concerns (Sadik & Ottenbreit-Leftwich, 2023; Yadav et al., 2016).

Most teacher education programmes in Switzerland require pre-service teachers to complete a basic digital education course through which they mostly learn basic media and CS-related content knowledge (CK), with less emphasis on designing effective CS-based learning tasks. Specifically designed training courses for teaching CS education at lower secondary school have been offered only recently (Schmalfeldt, 2021). The development of the CS masters in teacher education includes the task of outlining all components of the curriculum, which has to be partially completed first (Döbeli Honegger et al., 2019).

The number of pre-service teachers who choose to teach CS as a school subject remains small – at least in Germany and Switzerland (Bergner, 2021), which might be due to the fact that the schools' teaching conditions are not yet optimal for teaching CS. In Germany, for example, CS subject content is not yet compulsory in all federal states (Schwarz et al., 2021). Although there are some textbooks for CS available, these are hardly transferable from state to state, as the content and competences of the school subject CS are very different in each case (Bergner, 2021). Perhaps the most widely used textbook in Germany is the web-based teaching material "inf-schule". In Switzerland, the curriculum for digital education consists of a combination of computer and media science literacy. Most teachers, unfortunately, prefer teaching media over computer science (Döbeli Honegger et al., 2019); furthermore, CS is only partly an independent subject that needs to be integrated with other subjects as well. Another obstacle to CS education is that many of the pre-service teachers have not experienced CS education in the school setting themselves (Schmalfeldt, 2021). Schmalfeldt (2021) suggested to first focus on building up the subject content necessary for compulsory education for the CS master in view of the marginal CK of the pre-service teachers. For a similar reason, the CS teacher training at RWTH Aachen University in Germany is embedded in a teaching-learning lab with real groups of school students (Bergner, 2021) and with later in-field experiences complementing their education. Peer learning, as an additional strategy for teacher education, seems to be successful in increasing teachers' CS knowledge and confidence through sharing their expertise with fellow teachers (Hamlen et al., 2018). Collaboration among teachers is also recommended by Sadik and Ottenbreit-Leftwich (2023) because it is an essential component of effective CS teaching, which involves sharing resources (e.g. lesson plans and curricular activities) and modelling effective teaching practices.

Challenges in teaching CS

Before we report on the challenges of teaching CS, we would like to describe briefly what competencies teachers should have or need to acquire, as we will refer to them. Margaritis et al. (2015) divided these competencies into cognitive abilities and knowledge (i.e. PCK and CK) on the one hand, and motivational, volitional, and social dispositions and skills on the other hand. As you will later see, we have tried to include both aspects in our survey instrument. Recent research has highlighted PCK as a key aspect of effective CS teaching in K-12 schools (Hubwieser et al., 2013; Sadik & Ottenbreit-Leftwich, 2023; Yadav & Berges, 2019). Building on Shulman's (1986) construct of PCK – which is specific to each discipline – we followed the description by Yadav et al. (2022) who views the PCK of CS as the type of knowledge CS teachers need to be successful in providing effective CS instruction. These authors referred to a matrix by Hubwieser et al. (2013), in which PCK is conceptualised as fields of pedagogical operations and aspects of teaching and learning. Fields of pedagogical operations encompass the planning and design of learning situations, reacting to student's demands during the teaching process and evaluating teaching processes. Aspects of teaching and learning include learning content, curricula and standards, and subject-specific teaching concepts. Teacher educators of pre-service teachers should address all of the aspects of PCK that are needed to tackle the challenges during their CS internship (Yadav et al., 2017).

The following section is particularly significant for our study because it draws attention to specific requirements and challenges in CS teaching. The content of CS is often taught in the context of a project and/or problem-based learning (Evans Reding & Dorn, 2017; Fahrman et al., 2020), which makes it more difficult to prepare lessons, to keep all students active, and to guide them in their learning process (Malik & Zhu, 2023). Different prerequisites and interests of the students further complicate CS teaching in classes (Meelissen, 2008; Ryoo, 2019). Therefore, coursework alone is inadequate for preparing pre-service teachers to use CS in the classroom, as reported by Yadav et al. (2022).

A potential reason for this is that institutional CS courses focus on digital literacy skills rather than on how to integrate CS with classroom instruction (Russell et al., 2003), thereby providing few opportunities to incorporate different activities into specific content areas (DiBella et al., 2015; Yadav et al., 2014). Giannakos et al. (2015) reported that in-service teachers in their study with very good pedagogical and CK of their subject (algorithms) claimed they were less capable of transforming and effectively applying their knowledge to teaching. Therefore, these authors concluded that there was a need to train teachers so they would be able to identify the most common student misconceptions and be able to find ways to overcome them. Their results suggest that being a digital native does not necessarily equate with being a digital expert in the classroom (Sadik & Ottenbreit-Leftwich, 2023); pre-service teachers who know how to programme do not necessarily know how to foster this knowledge in their future students (Pollock et al., 2015). Therefore, some teacher educators have developed didactic implementations—e.g. with visual coding as content – with their pre-service teachers assigned to foster their CS PCK and self-efficacy beliefs (Bean et al., 2015; Piedade et al., 2020).

We now move to the second branch of the necessary competencies for CS teaching mentioned by Margaritis et al. (2015): the motivational, volitional and social dispositions and skills. Here, too, specific challenges to the subject become apparent. Pre-service CS teachers reported that their self-efficacy related to the use and integration of technology and their level of anxiety about managing the classroom impacted the way they applied CS in their teaching practices (Kartal & Başarmak, 2022). Self-efficacy and affect are interrelated (Bandura, 1982). Computer anxiety is a well-known problem that interferes with the effective implementation of CS by teachers in schools with compulsory education. Zha et al. (2020) reported that many pre-service teachers showed negative emotions, such as anxiety, when they started to learn about block-programming. The authors concluded that the pre-service teachers needed to feel comfortable in order to develop positive attitudes towards coding. Therefore, Evans Reding and Dorn (2017) have recommended implicit observations of teachers' affective responses when conducting CS programs. Kay (2007) reported that happiness (curiosity, satisfaction, and excitement) was experienced frequently by pre-service teachers and that negative emotions (anxiety, anger, and sadness) were experienced, on average, between "never" and "sometimes" when software was learned at the university. Moderate positive developments were observed over time: negative emotions decreased, and happiness increased. These developments had a positive impact on the use of computers in the field. Increased happiness and reduced anxiety were correlated with the frequency of computer use in field placements.

With respect to beliefs and attitudes, gender might be an additional obstacle to the effective implementation of CS by pre-service teachers: women seem to have less confidence than men do about their CS skills, and women are much less visible than men in the CS world of work, especially in Switzerland (Cussó-Calabuig et al., 2018). In a study by Tondeur et al. (2018), however, neither gender nor age had an impact on pre-service teachers' beliefs, whereas a study from Estonia found more positive perceptions among male pre-service teachers and fewer positive perceptions with regard to age (Luik et al., 2018). Repenning et al. (2019) concluded that gender should be considered when developing CS courses for pre-service teacher education. In their study, the self-efficacy of female pre-service teachers did not develop as expected in their mandatory CS courses.

According to Broos (2005), computer anxiety is more frequently observed in women than in men, and there are different experiences between the genders: men who have only recently been using a computer become very computer confident and show less computer-related anxiety, whereas women's computer-related anxiety diminishes noticeably only after they have been using a computer for a year. Ruttenberg-Rozen et al. (2022) described the experiences of a female pre-service teacher learning to code for mathematics teachers: limited previous experience with coding content and with applications of coding in the classroom setting led to negative emotions despite being a pre-service teacher with high levels of mathematical knowledge and self-efficacy beliefs. This also introduces a transition to the next section on internships.

CS internships and teaching experiences

In the following section of the paper, the aspects of teacher training, the challenges for CS teaching and the internships are now brought together. We start with the role of the mentor and then go on to consider the importance of a good learning environment for the pre-service teacher to have a positive experience. In our view, the learning environment in our study was particularly conducive to learning experiences (see the following section).

An internship in a school is crucial for pre-service teachers to transfer the CS knowledge they acquire during their higher education and apply it to their teaching practice (Buchholz et al., 2013; Hazzan & Lapidot, 2004; Hazzan et al., 2010; Tondeur et al., 2017). According to several studies (Elstad & Christophersen, 2017; Yeşilyurt et al., 2016; Zhou et al., 2020), lack of self-efficacy is a major obstacle to implementing effective CS instruction, which is urgently needed in schools. A decrease in self-efficacy mostly occurs when new teachers assume full responsibility for their teaching during their first year of practice (Hoy & Spero, 2005). Supporting pre-service teachers during their internship experience appears to strengthen their ability to graduate with a teaching degree and develop resilience in teaching for their later career (Pfitzner-Eden, 2016). Hence, support by a mentor teacher during an internship is critical for the development of strong self-efficacy (Lemon & Garvis, 2016). Mentors should serve as positive role models and encourage pre-service teachers to employ the computer activities used for the first time in their future daily teaching (Bullock, 2004). As mentioned previously, there are too few experienced CS teachers in many countries who can serve as effective role models in teacher internships to integrate CS into their lessons (Brinda et al., 2009; Pollock et al., 2015; Sadik & Ottenbreit-Leftwich, 2023). As a result, pre-service teachers report, for example, that they do not encounter many student-centred CS learning situations during their internships, which is a prerequisite for learning how to problem-solve for CS learning situations (McGarr & Gavaldon, 2018; Røkenes & Krumsvik, 2016; Taylor, 2021). Moreover, experienced teachers who serve as mentors for CS often have deep-rooted teaching habits and practices that are unfavourable. Prasse et al. (2017) noted that compared to teachers with a constructivist pedagogical attitude, those with a stronger teacher-oriented learning practice often see fewer advantages for the use of digital tools and such that are not favourable (e.g. illustration of the teaching content and simplified lesson organisation) than those with a student-oriented approach. Those with teacher-oriented practices have more concerns about negative consequences (the possible loss of control and the potential for distraction), and therefore, avoid student-oriented methods.

Bergner's (2021) recommendation that due to the great heterogeneity of the learners in CS, it is important for pre-service teachers to acquire concepts for the individual support of students' learning goes in a similar direction. As mentioned above, individualised CS learning is rather unpopular with many experienced teachers (Prasse et al., 2017), which might be due to their lack of CK of CS (Pollock et al., 2015).

Learning environments for CS-education

As mentioned, we will now briefly discuss the learning environment used. What would learning environments that are conducive to pre-service teachers' acquisition of CS knowledge during the internship look like? Sadik et al. (2020) suggested that secondary CS teachers should learn about student-centred strategies (problem-based learning and pair programming) and how to guide their students during the learning process. Merely adding more CS-topics to the curriculum is less beneficial for school students' learning of CS than is teaching problem-solving and computational thinking (Sadik & Ottenbreit-Leftwich, 2023). Furthermore, embedding CS in other subject areas might be helpful. Such learning differs from teaching CS as part of a stand-alone course in which the tasks that school students are given tend to be divorced from real-world problems and applications (Weintrop et al., 2016). Rich, open-ended, inquiry tasks for mathematics and science that are intentionally designed to engage school students in higher-level thinking are effective learning opportunities for CS (Rich et al., 2020). A sense of authenticity and real-world applicability is important in the effort to motivate secondary school students to engage in computational and scientific activities (Sadik & Ottenbreit-Leftwich, 2023). Finally, opportunities for assisting pre-service teachers to exchange experiences has additional benefits – emotional and intellectual (Sadik & Ottenbreit-Leftwich, 2023).

The learning environment in our study for the secondary school students was designed accordingly and served as a model for teaching CS at the secondary school level. The materials we used consisted of a wearable device, specifically, a type of smart textile (Chen, 2015) that could be sewn, for example, onto a T-shirt. While our LED matrix delivered stimuli as a visual message, other outputs of smart textile devices could be electro-thermal or acoustic. The LED matrix was connected to a micro-controller (micro:bit), which is a pocket-sized codeable physical computing device (Sentance et al., 2018). The block-coding language MakeCode for micro:bit (makecode.microbit.org) was used to operate the computing device. In each of the three courses, two pre-service teachers assisted the course leader, who served as their role model for teaching. This description of our learning environment begs the question about whether it has been effective in providing positive learning experiences for student teachers.

Present study

In the following, we summarise again what was explained in the section "CS internships and teaching experiences" and what is central and unique to our study. Due to the lack of opportunities for future CS secondary teachers to gain practical experience, we looked for a way for them to experience this as assistants in out-of-school CS courses for the target level. We compared the development of their knowledge and attitudes with those of their fellow students without these experiences. Our aim was to strengthen the assisting pre-service teachers' self-efficacy, reduce any negative emotions and generally promote their PCK of CS. For the latter, the typical rather open character of CS learning environments should be mentioned in particular, which entails many unprepared situations for CS teachers. Such experiences can alleviate the so-called "practice shock" when new teachers start teaching. To clarify the success of our approach, the following questions arose.

Research questions

All the participating pre-service CS teachers acquired theoretical PCK of CS at the teacher institute. Our first research question (RQ1) focused on whether there were differences in attitudes and self-perceived knowledge between the two groups (see Figure 1). Hypothesis 1 predicted that pre-service teachers assisting in the technology centre – the intervention group – would develop higher levels of positive attitudes and self-perceived PCK of CS over time than would pre-service teachers in the control group. Our second question (RQ2) was related to the emotional experiences of the assisting pre-service teachers during the three coding courses. We wondered how these emotions developed over time and what short statements the students made about them. Hypothesis 2 posited that there would be an increase in their positive emotions and a decline in their negative emotions over time.

Methods

Research design

Based on a quasi-experimental control group design, we investigated whether the pre-service teachers in the intervention group developed a higher level of instructional self-efficacy beliefs and a higher level of knowledge for teaching CS over time than the pre-service teachers in the control group did. The duration of the entire project lasted one year, with its commencement at the beginning of 2020; the intervention was implemented from August 2020 until February 2021 (see Figure 1).

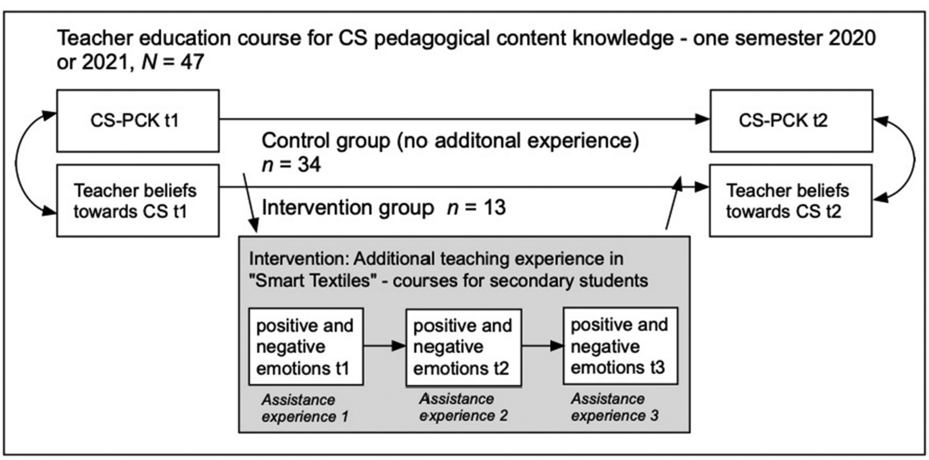

Figure 1. Research design; CS = computer science; PCK = pedagogical content knowledge.

To test hypothesis 1, we analysed quantitative data derived from a questionnaire that was administered to both study groups ($N = 47$). In addition, we analysed the data collected from the intervention group ($n = 13$) using the experience sampling method (ESM) to answer hypothesis 2.

Sample

The intervention group consisted of 13 pre-service teachers, each of whom functioned as an assistant three times during a one-day course for secondary school classes on computer coding, with the help of smart textiles. All participants volunteered in response to a call within the institution. They were paid a wage commensurate with the job requirements. We expected to recruit a higher number of assistants, but many courses were cancelled because of COVID-19; hence, more assistants could not be hired. A larger sample ($n = 34$), which served as the control group, consisted of pre-service teachers who had acquired only theoretical knowledge from the theory-based course on PCK for teaching a mandatory CS course for all ($N = 47$) participants. This one-semester course at the university had the following goals:

The student teachers:

- are able to motivate students to learn the subject content of CS and can legitimise the subject (contribution to general education – "Bildung");
- can prepare CS lessons in a way that is appropriate for the target population, taking into account the subject's didactic and principles from learning psychology;
- can teach strategies of problem-based learning;
- can identify typical sources of errors made by students; and
- know about important online resources and initiatives for the promotion of CS education.

Our sample consisted of the entire student-teacher cohorts for teaching CS as a subject in secondary school in 2020 and 2021. Missing data in this study involved only specific items on the questionnaire.

The mean age of the pre-service teachers was 26 ($SD = 7$) years and most of them were in their 6th semester of study. Gender was not equally distributed (14 females and 33 males), and approximately half of the participants had experience teaching CS in the field, mostly through an internship at school. The pre-service teachers in the control group were younger ($M = 23$) than the teachers in the intervention group ($M = 27$) and there was a higher percentage of females (almost equal) in the intervention group than there were in the control group. Furthermore, the participants in the intervention group had less internship experience in teaching CS than did those in the control group. However, there was no difference in the general in-field teaching experience. Similarly, knowledge levels related to prior job experience or prior study of other subjects were comparable. The training to become a teacher of CS at the upper secondary level was part of the training required for various subjects, indicating that the pre-service teachers had pedagogical knowledge of various subjects.

Procedure

The pre-service teachers from the intervention group assisted course instructors and secondary school students in the 'Smart Textiles' computer-coding course. The course, titled, "Creativity in Science and Technology: Smart Textiles", focused on scientific and technical problems that were solved with the help of Microsoft's MakeCode for micro:bit, which is a visual programming language. The so-called "smart textiles" were to be designed in the afternoon as part of a workshop, so the morning consisted of preparatory tasks for this goal. The secondary school students learned the principle of input – processing – output (IPO), which is important for understanding how technical devices work (Sentance et al., 2018). Next, the IPO principle had to be applied to the first task, titled, "Messenger with Morse Code". For this task, the students had to programme a messenger that would communicate via visual Morse code. The first task required the most guidance, and the openness and complexity of the tasks increased as the course progressed. For the second task, the secondary school students had to connect the LEDs correctly, control them, and switch them on and off. After the second task was completed, a push-button had to be built with assistance, to make analogue Morse coding possible. The last task was to programme the Morse code. After a coffee break, the LEDs were increased from one or two, to a LED strip with 10 LEDs and debugging as a working technique was introduced. The students investigated several programming errors, which were developed by the course leaders. It was the students' task to correct the errors using the trial-and-error method.

After the lunch break, the working material was changed from an LED strip to a LED matrix, on which there were 256 LEDs. A flag-programming task was required to explore the structure of the matrix. The goal was to program different flags for the "smart shirt". The basic idea for the "smart shirt" was to attach a LED-fabric matrix to a T-shirt and use it to convey messages or images. Design goals were associated with this task and openness allowed for different solutions. Next, a second smart shirt, specifically, a weather indicator, needed to be created, i.e. a shirt that reacts to light intensity and displays different motifs, depending on the light intensity. As a final task, the students had to develop a "bicycle shirt", with a matrix on the back of the shirt on which one could show flashes to the left (A) or the right (B) by pressing buttons A and B on the micro:bit. This would provide a warning to following road users. This bicycle shirt was analogous to the Emoji Jacket, which was developed by Ford (Ford media center, 2020)

The pre-service teachers were introduced to the aims of the computing workshop, the tasks of the participants, and their roles as assistants. They were asked to complete all tasks themselves at home before they began the first of the three courses in which they assisted the course instructor and secondary school students. In each course, every pre-service teacher had to complete a short electronic questionnaire using a tablet or mobile device twice, i.e. one survey immediately before and one at the end of a course unit (event). We asked the pre-service teachers to report their current emotions about teaching CS using the ESM, which was performed using event-contingent sampling. Before and after the course, a longer survey was administered to measure the pre-service teachers' general attitudes. The pre-service teachers from the control group who took only the PCK semester course for teaching CS at the teacher university also completed the same questionnaire.

All of the pre-service teachers in the intervention group followed the guidelines presented at a short course that was conducted to provide PCK about how to motivate secondary school students to acquire programming skills and how to teach CS in a manner appropriate to the level of the target population. After completing the course, the pre-service teachers were expected to know how to teach strategies for problem solving in this course and how to identify typical sources of errors.

Instruments

Attitudes (traits)

Our questionnaire, which was designed to measure pre-service teachers' level of knowledge for teaching CS, was based on the study by Liu (2016). His framework for measuring technological pedagogical content knowledge (TPACK) consisted of scales that combined teacher education programs, experiences from field-based internships, attitudes and beliefs, and the implementation of technology integration. We used items from a questionnaire for TPACK because we did not find any items for CS PCK. The items were translated and adapted for use in our study (Appendix). Instead of using the term 'technology', we used the German term 'Informatik' in accordance with the Swiss curriculum and because this term was the best translation of the term 'computer science' (Hubwieser et al., 2011). Because Liu's (2016) study used only two items from each scale for structural equation modelling (SEM), we developed an additional item for each scale in order to measure their reliability using Cronbach's alpha. All the Cronbach's alphas ranged from .58 to .89 at Time 1 and .71 to .92 at Time 2. This indicated a sufficient scale reliability.

Momentary emotions (states) and related aspects

On each of the three days of the course, a short questionnaire was administered, which had two items related to negative emotional states (insecurity and discomfort) and two items related to positive emotional states (enjoyment and pride). All participants were asked to complete the short survey twice during each lesson: once immediately before they started to assist the secondary school students and course instructors and once following the end of the course. We used a self-report 10-point rating scale with two poles to assess whether the student teacher was, at that moment, feeling joyful, uncomfortable, proud, or insecure (10 = *absolutely true* and 1 = *absolutely untrue*). The measurement of each item twice during each course session yielded a total of 6 measurements for each student teacher and item. Finally, the pre-service teachers were asked to provide short statements describing what they worried about (before each course), and what was difficult and what went well (after each course).

Data analysis

Due to the small sample size, we conducted only basic analyses (i.e. *t*-tests, repeated measures analysis of variance [ANOVA], and regression analyses). The *t*-test is appropriate for small sample sizes and quite robust in analyses of samples from non-normal distributions and samples with unequal variances. However, the low power of the small sample size made it more difficult to detect effects. Nevertheless, based on a power calculation (G*Power) for a multivariate analysis of variance with repeated measures and an expected effect size of $f = .30$, a power of .80 was sufficient. These calculations and the sample size are comparable to the research of Han et al. (2017), that analysed responses to similar questions. However, if the variances between the groups (e.g. the standard deviation) are large, the significance level will be more difficult to reach.

Data on the emotions of the pre-service teachers before and after their course assistance were tested for normality, linearity, multicollinearity, and homoscedasticity. Levene's test was used to verify the assumption of equal variances for the *t*-tests. Hedges' g, which provides a correction for small sample bias, was used instead of Cohen's d to estimate the standardized difference between the means of the two study populations. Developments over time were analysed using a one-way ANOVA with repeated measures, which is known to be robust to violations of the normal distribution assumption.

Results

The first research question addressed in this paper was answered by the means of the *t*-tests and the repeated measures ANOVA, and by using the scales that described attitudes toward and self-perceptions of PCK for teaching CS. We start with differences between the groups per time (Table 1). The results showed some significant differences between the pre-service teachers in the intervention group and those in the control group at Time 1 (T1). The assisting pre-service teachers had significantly higher scores than the teachers in the control group had on measures of content knowledge: $t(47) = -2.60$, $p < .05$, $g = 0.83$ and peer support: $t(47) = -2.22$, $p < .05$, $g = 0.71$. Their scores on self-efficacy, $t(47) = -1.80$, $p = .08$, $g = 0.58$, and PCK, $t(47) = -1.79$, $p = .08$, $g = 0.57$, were considerably higher than the scores of those in the control group, however, the significance level was not reached. Except for peer support, all variances were assumed to be equal. We analysed the data to check for gender differences and differences based on knowledge acquired outside of the courses or before the project's initiation. There were no gender effects, but pre-service teachers who had acquired knowledge in a previous, different field of study, an apprenticeship, or through teaching experience scored higher on measures of

Table 1. Descriptive statistics for the scales.

	Intervention group (*n* = 13)				Control group (*n* =34)			
	T1		T2		T1		T2	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attitudes about teaching CS	5.23	.55	5.17	.80	4.97	.76	4.93	.74
Belief in the effectiveness of CS	4.70	.84	4.90	1.01	4.27	.81	3.88	1.10
Self-efficacy for teaching CS	4.90	.63	5.23	.75	4.46	.78	4.70	.98
Mentor CS support	3.91	.87	3.95	.88	3.25	1.23	3.28	1.21
Faculty CS support	3.63	.84	3.91	.83	3.58	1.22	3.60	.91
Peer CS support	4.26	.76	4.97	.63	3.63	.90	3.78	1.13
CK	5.04	.56	5.13	.63	4.42	.78	4.69	.69
PK	4.51	.75	4.44	.74	4.17	.86	4.42	.70
PCK	4.29	1.04	4.13	1.24	3.76	.88	3.97	1.06

Note: *N*= 47; 6-point Likert scale (6 = strongly agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = strongly disagree); CS = computer science; CK = content knowledge; PK = pedagogical knowledge; PCK = pedagogical content knowledge.

self-efficacy and self-perceived PCK than their counterparts. At Time 2 (T2), the situation was similar to that of T1, except for PCK, which exhibited no group difference this time.

Liu (2016) used SEM to analyse the relationships between the scales; however, our sample size was too small to conduct such an analysis. Instead, we investigated the relationships using Pearson product-moment correlations. Liu clustered the scales into three groups of three scales per group (1–3, 4–6, 7–9, in Table 2). Similar to Liu's SEM results, we found moderate to strong correlations between the scales' measures of attitudes (1–3), and the knowledge acquired during teacher education (7–9). However, the scales' measures of field-based experience (4–6) did not correlate because peers were viewed as a different and better source of CS problems than were the mentors on the faculty or in the field. Furthermore, the self-efficacy beliefs correlated strongly with CK and PCK; thus, pre-service teachers with stronger self-efficacy beliefs for teaching CS seemed to have a larger knowledge base with respect to CS.

We conducted several ANOVAs with respect to time and group to answer our first research question and hypothesis 1 regarding differences in attitudes and knowledge and to explore the impact of our intervention on the scales. Levene's test was applied to check for homogeneity of variance. However, none of the analyses were significant at the $p < .05$ level. A moderate—$\eta^2 = .077$, Cohen (1988)—but non-significant effect was found for belief in the effectiveness of CS for learning, which was an interaction effect between time and group $F(1, 43) = 3.57$, $p = .066$. The time effect was not significant, indicating there was no general growth over time (see Table 3). More precisely, the control group's scores decreased and those of the intervention group increased. The moderate interaction but non-significant effect indicates that variation in the effectiveness of CS for learning could be explained partly by the groups' development over time.

A further non-significant effect with a moderate effect size ($\eta^2 = .068$) was found for peer CS support. The interaction between time and group was: $F(1, 43) = 3.13$, $p = .084$

Table 2. Inter-correlations among the scales at Time 1.

		1	2	3	4	5	6	7	8
1	Attitudes about teaching CS								
2	Belief in the effectiveness of CS	.52**							
3	Self-efficacy for teaching CS	.36*	.38**						
4	Mentor CS support	.16	.22	.29*					
5	Faculty CS support	.10	.22	.21	.80**				
6	Peer CS support	.31*	.36*	.50**	.31*	.12			
7	CK	.49**	.35**	.59**	.24	.12	.43**		
8	PK	.41**	.43**	.54**	.37*	.19	.41**	.67**	
9	PCK	.40**	.32*	.71**	.43*	.27	.50**	.41**	.50**

$N = 47$; **all coefficients are significant at $p < .01$; *all coefficients are significant at $p < .05$; CS = computer science; CK = content knowledge; PK = pedagogical knowledge; PCK = pedagogical content knowledge.

Table 3. Results of the analysis of variance for belief in the effectiveness of computer science for learning by time and group.

Source	*Df*	*MS*	*F*	*p*	η^2
Time	1	.099	.271	.606	.006
Time × group	1	1.303	3.567	.066	.077

$N = 47$; 6-point Likert scale (6 = strongly agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = strongly disagree).

Table 4. Results of the analysis of variance for peer computer science support by time and group.

Source	Df	MS	F	p	η^2
Time	1	3.781	9.066	.004	.174
Time × group	1	1.306	3.131	.084	.068

N = 47; six-point Likert scale (6 = strongly agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = strongly disagree).

(see Table 4). In both groups, peer discussions on the application of CS in the classroom became more frequent over time; however, sharing experiences was more often observed in the intervention group when both groups of pre-service teachers were compared.

Herewith we note with reference to research question 1 that we did not find any significant differences between the two groups over time. In particular, the control group had high standard deviations at time t2, which made it more difficult to reach significance. However, we detected moderate effect sizes for two scales in favour of the intervention group as expected in hypothesis 1.

In the following section, we report the study's findings related to the research question and hypothesis 2 on the development of emotions. Hierarchical multiple regression was used to assess the effect of time on the emotions of pre-service teachers assisting in the course. We tested several predictors (i.e. time, gender, previously acquired knowledge, internship experience, and semester) for their relevance in explaining the variance in the data. The final models included time and internship experience for the two negative emotions. None of the other predictors showed a significant effect (Table 5). No changes over time were found for the emotional states of enjoyment or pride; the pre-service teachers' scores for both emotions during all three courses were high (see Figure 2). In contrast, the pre-service teachers' scores for the negative states of insecurity ($\beta = -.35$) and discomfort ($\beta = -.22$) were significantly reduced over time. In addition, those who had experience from a previous internship had fewer negative emotions related to assisting in the courses. Models 3 and 4 explain $R^2 = 28.2\%$ and $R^2 = 10\%$ of the changes over time for feeling insecure or uncomfortable.

With respect to our second hypothesis the expected increase in pre-service teachers' positive emotions did not occur but a decline in their negative emotions over time occurred as expected. It must be pointed out that their positive emotions were already at a relatively high level from the beginning.

Open-ended responses to the emotions questionnaire indicated a more nuanced understanding of the results. The pre-service teachers who were assistants were asked to note the worries they had *before* the courses started. Over the three courses, the

Table 5. Results of the regression analyses for emotions over time.

		1 Enjoyment		2 Pride		3 Insecurity		4 Discomfort	
	Variable	B	p	B	p	B	p	B	p
1	Time	.21	0.66						
2	Time			.10	3.94				
3	Time					−.35	.001**		
	Internship yes					−.40	.000**		
4	Time							−.22	.047*
	Internship yes							−.23	.043*

N = 13 × 6 time points; 10-point scale with two poles (1 = not at all true and 10 = absolutely true); **All coefficients were significant at $p < .01$; *all coefficients were significant at $p < .05$.

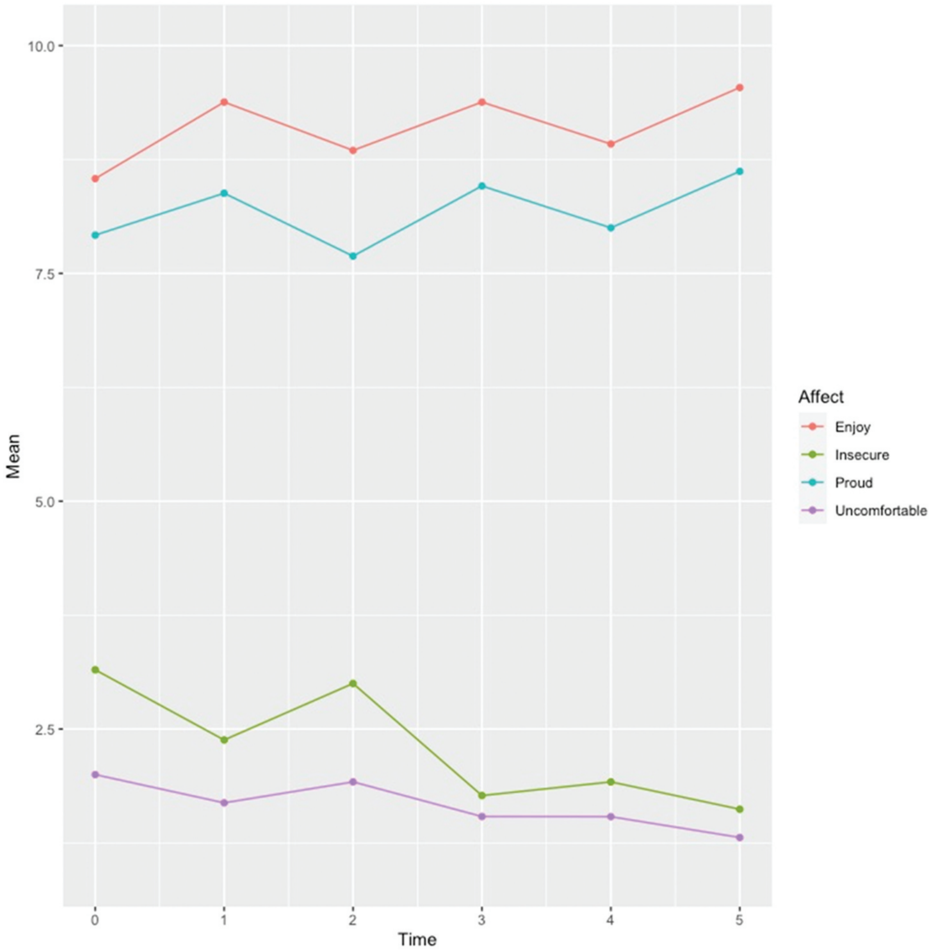

Figure 2. Means for positive and negative emotions of pre-service teachers over time (intervention group only); $N = 73$ time-points; a 10-point scale with two poles (1 = not at all true and 10 = absolutely true) was used to assess the pre-service teachers' momentary (states) emotions.

number of notes declined, and by the third assistance, no worries were noted. What the assisting pre-service teachers reported mostly pertained to lack of CK and the fear of not being able to provide support (i.e. PCK). Apparently, some of them did not prepare for their second course and feared they might have forgotten part of the necessary CK. One pre-service teacher feared not being able to motivate secondary school students and another had worries about classroom management. These topics were more about PK. When asked what had worked well *after* the course, they mostly stated that they had been able to provide adequate support for the students during the coding exercises, and some of them mentioned that they had succeeded in motivating the students. Further topics included satisfaction with their classroom management or communication with the secondary school students. What did not work well? The pre-service teachers reported concerns related to their lack of CK or PK for student support and classroom management, or not being able to motivate the secondary school students.

Discussion

Our research aimed to explore the impact of a field-based internship for secondary pre-service teachers who assisted three times in a day-long course for secondary school students. The pre-service teachers' experiences in the internship related well to the goals of the theoretical PCK course at the teacher institution. The surroundings of the coding courses were authentic, as they were held in a start-up incubator. This means that in the building where the courses took place there were also younger entrepreneurs who were developing new technological products. In line with recommendations from Dickes and Farris (2019), we used a cross-curricular design for the course, combining CS, science, and design, thereby motivating both boys and girls (Katterfeldt et al., 2009). The results for the secondary school students are presented in a study by Schmid et al. (2022).

Hence, our pre-service teachers experienced an authentic learning environment with real secondary school students, which should have enabled them to strengthen their competencies for teaching CS and their self-efficacy beliefs (Mouza et al., 2022). Overall, we could not find any significant differences between the groups over time, contrary to expectations (RQ1). Based on the self-perceptions of the pre-service teachers' in the intervention group, it seemed that they had already possessed both characteristics to a greater extent than their fellow student teachers did. Hence, there was a certain bias with respect to the two groups. However, in the end, at T2 of the data collection, there were fewer differences between the two groups with respect to knowledge. There was a downward trend or a plateau of the knowledge scores in the intervention group and an upward trend in the control group. This was not the case, however, for pre-service teachers' beliefs and attitudes. Here the moderate effects – although not significant – favoured the pre-service teachers in the intervention group. Specifically, it seemed that the pre-service teachers in the intervention group were more able or willing to discuss and share their experiences in the peer group, compared to those in the control group. According to Hamlen et al. (2018) and Sadik and Ottenbreit-Leftwich (2023), peer learning is a fruitful strategy for increasing teachers' CS knowledge.

Computer anxiety is often an issue, particularly in CS education; therefore, we observed the development of the assisting pre-service teachers' emotions (RQ2), although we limited their number to four emotions. In contrast to the study by Kay (2007), which was conducted at a university, our pre-service teachers showed stable positive emotions in all three courses. However, the reduction of negative emotions over time was comparable. Pre-service teachers with more experience in the field reported having fewer negative emotions during all three assistantships.

How can these results of our intervention be interpreted? On the one hand they are positive because beliefs and attitudes are important for motivating pre-service teachers to implement CS in the classroom later, when they begin teaching as novices in the field. However, on the other hand it seemed that the assisting pre-service teachers realised that their knowledge bases for teaching CS were not yet sufficient to always support secondary school students with individual problems, similar to Pollock et al. (2015). Therefore, their knowledge did not show a larger increase than that of the control group. Moreover, it was perhaps their PCK that was challenged mostly by reality. They had difficulty seeing solutions for the specific problems of the students and communicating them to the students in a pedagogically meaningful way, which was also found in a study by Kartal and Başarmak (2022). The statements of the pre-service teachers assisting in the course, which were collected through the ESM, confirmed this possibility. A frequent topic was how well they were able to support the secondary school students as they conducted the coding exercises, and later, it was how well they understood the students' individual project ideas for the design of the message on the LED matrix and whether they were able to provide helpful feedback. Both concerns were related to their PCK. This experience would be difficult to provide in a university; therefore, its location in an authentic learning environment with secondary school students was more appropriate (Bergner, 2021). Although the initial worries of the participating pre-service teachers about their possible lack of PK were similar to those reported by Kartal and Başarmak (2022), (e.g. student motivation and classroom management), these concerns lessened over time.

Where can we build on other research and what are the implications? Yadav et al. (2017) recommend involving pre-service teachers directly in CS projects embedded in the classroom. We took a different approach to our project by giving the pre-service teachers an opportunity to observe course instructors practicing PCK for CS and to assist them without having to assume full responsibility for teaching before they were ready. In their study, Yadav et al. (2014) found that pre-service teachers in an intervention group were better able to see ways to integrate algorithms in their own classrooms than the pre-service teachers in the control group were. In our study, this ability was not investigated; instead, we enquired about their self-perceived PCK, but it could be that such a specific question related to coding topics might have resulted in differences between the groups in our study as well. The argument is that pre-service teachers without experience in the field only have a vague notion of what problem-solving and coding activities might look like in the classroom (Mouza et al., 2017). Hence, they probably estimate their PCK based on their CK. Finally, similar to the findings of Yadav et al. (2014), we did not encounter gender differences between the pre-service teachers, which is encouraging.

Our study has some limitations. For example, the participants were self-selected, which might have led to a bias in the values of the two groups (Vallett et al., 2018). The pre-service teachers who volunteered probably had more positive attitudes towards CS than those in the control group. However, in this study we were more interested in comparing developments and believe that the so-called praxis-shock was the factor that had the most influence on the respective differences within the two groups (Sadler, 2006), as discussed above. Overall, the self-reported PCK measurements may involve several distortions, among them are: misunderstandings of PCK or beliefs; overestimations or underestimations of PCK; and specific cultural influences (Su & Foulger, 2019). Nevertheless, Max et al. (2022) recently showed that self-assessments are adequate instruments to capture the CS competence of pre-service teachers, at least for those teachers with a moderate or high level of prior CS knowledge. Those authors also reported that pre-service teachers overestimated their knowledge when it came to the application of CS knowledge in a teaching scenario, which might also have been the case for our pre-service teachers assisting in a coding course for secondary school students. More problematic was the construction of valid items for a CS knowledge questionnaire. We followed the procedure described by Liu (2016), but we think that the items we used should be refined further to measure CS knowledge more precisely.

This brings us to the conclusions. As suggested by Mouza et al. (2017) and Yadav et al. (2017), our study explored another pedagogical strategy for including problem-solving and coding in the curricula of teacher education. Although no significant differences were found between the two study groups, two moderately positive effects related to belief in the effectiveness of CS learning and the use of peer support by the assisting pre-service teachers appeared. Their self-reported positive experiences in an authentic computer coding teaching environment were confirmed by their decline in negative emotions. The results of our research might contribute to the expansion of our knowledge of meaningful educational experiences for the CS education of pre-service teachers. Overall, our setting seems to us to be rich in learning: first, through the picture of the model CS lesson with all its complex facets; and second, through the opportunity to test acquired competencies. It was also important that emotional experiences be remembered positively. We think that there is no corresponding modelling of CS lessons in ordinary internships because mentors are generally unaware of them.

Our approach had difficulty empirically establishing positive learning experiences and should be tested by other teacher educators because we only worked with a limited number of participants and courses. Although there are many CS topics in teacher education, we agree in line with Sadik and Ottenbreit-Leftwich (2023) that pre-service teachers probably need less education related to various CS topics and more education on student-oriented CS teaching methods and student scaffolding. Overall, the integration of CS with other STEM (Science, Technology, Engineering, and Mathematics) subjects – as in our study – has proved beneficial for pre-service teachers and secondary school students (Yadav et al., 2017). Given these accomplishments, an important extension of the present study would be to explore the ability of assisting pre-service teachers to transfer their acquired PCK to their own classrooms when they begin their professional lives. This includes the more general question of how teacher institutes can best provide CS education for the transfer of such knowledge.

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Notes on contributors

Robbert Smit is a professor at the St. Gallen University of Teacher Education. Robbert has research expertise relating to areas of STEM and teacher education. He is a former secondary school teacher.

Clemens Waibel is a research assistant at the St. Gallen University of Teacher Education and course leader in the field of computer science. He also teaches at secondary school.

Rachel Schmid is a scientific collaborator at the St. Gallen University of Teacher Education. Her recent thesis explored the role of error orientation with respect to CS learning.

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Appendix

Computer Science Questionnaire; Items were adapted from Liu (2016), and each scale was extended by one item.

Construct	Item	Statement
Pedagogical knowledge α = .71/.71	PK 01	My pedagogical knowledge from the TU enables me to integrate computer science into the classroom.
	PK 02	During my education at the TU, I was able to observe lessons with computer science applications to enhance my own teaching skills.
	PK 03	Through my education at the TU, I acquired the ability to convey knowledge in an easily understandable way using computer science.
Content knowledge α = .80/.71	CK 01	My computer science expertise acquired at the TU enables me to integrate computer science into the classroom.
	CK 03	In computer science education, I acquired knowledge that enables me to meet the demands of teaching.
	CK 04	I have the subject knowledge to implement computer science instruction well.
Pedagogical content knowledgeα = .82/.88	PCK 01	In my lessons, I applied computer science to enhance student learning of specific subject content.
	PCK 02	I designed lessons that best combined specific subject content, computer science applications, and instructional methods.
	PCK 03	I designed lessons that optimally combined subject knowledge, computer science applications, and teaching methods.
Mentor support for teaching computer science α = .88/.88	ME 01	My mentor encourages me to use computer science in the classroom.
	ME 02	I can ask my mentor for advice on the use of computer science during classroom practice.
	ME 03	My mentor can recommend appropriate applications in computer science for appropriate teaching sequences.
Peer support for teaching CS α = .68/.86	PE 01	I can ask students in my mentoring group for advice on how to apply computer science in the classroom.
	PE 02	I can share my experiences about integrating computer science into the classroom with students in my mentoring group.
	PE 03	I can give advice to someone in my mentorship group on how to apply computer science in the classroom.
Faculty computer science support α = .88/.75	PL 01	My internship supervisor can advise me when I want to use computer science in the classroom.

(*Continued*)

(Continued).

Construct	Item	Statement
	PL 02	My internship supervisor can support me when I want to integrate computer science into the classroom.
	PL 03	My internship supervisor encourages me to integrate computer science into the classroom.
Beliefs about the effectiveness of computer science learning α = .71/.89	BLF 01	I believe that teaching integrating computer science is more effective than traditional teaching.
	BLF 02	I believe that computer science is critical to improving student learning.
	BLF 03	I believe that student motivation is increased by using computer science.
Self-efficacy beliefs about teaching computer science α = .81/.92	Self-efficacy 01	I have confidence in my ability to use applications of computer science for teaching in my next lessons.
	Self-efficacy 02	I have sufficient skills to design lessons with the use of computer science.
	Self-efficacy 03	I have the confidence to design a learning activity for students to use computer science applications.
Attitudes toward computer science teaching α = .68/.80	Attitude 01	I feel that teachers should have the ability to integrate computer science into the classroom.
	Attitude 02	I think teachers should take time to plan activities related to computer science.
	Attitude 03	I think that teachers should be experts in using computer science in the classroom.

Note: TU = University of teacher education; Cronbach's α values for t1/t2; 6-point Likert scale (6 = strongly agree, 5 = agree, 4 = somewhat agree, 3 = somewhat disagree, 2 = disagree, and 1 = strongly disagree); PK = pedagogical knowledge; CK = content knowledge; PCK = pedagogical content knowledge; ME = mentor; PE = peer; CS = computer science; PL = faculty; BLF = belief.