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Finnish teachers' and students' programming motivation and their role in teaching and learning computational thinking

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Introduction: Despite the growing importance of teaching and learning computational thinking (CT) through programming in schools, research has shown major individual differences in teachers' instruction emphasis and students' skills in these topics.

Objective: This study aims to shed further light on the role that teachers' and students' programming motivation plays in CT.

Methods: The topic is approached from the viewpoint of the self-determination theory, which can help to understand teachers' instruction and students' learning. Our sample consisted of Finnish Grade 8 teachers (N = 1,853) and students (N = 2,546) who participated in the International Computer and Information Literacy Study (ICILS) in 2018. Focusing on teachers' CT instruction emphasis, students' CT test scores, and the Intrinsic Motivation Inventory, we investigate (1) distributions of teachers' and students' responses to intrinsic and extrinsic programming motivation questions, (2) associations between teachers' and students' programming motivation and their background factors, and (3) associations between programming motivation and teachers' CT instruction emphasis and students' CT test scores. The data was analyzed by examining descriptive statistics, computing mean differences and correlation coefficients and by performing (multiple) linear regression models.

Results: The results showed that teachers had high extrinsic programming motivation, but the extent of their intrinsic programming motivation varied widely based on their prior programming teaching experience, subject taught, and gender. Students, in turn, reported both high intrinsic and extrinsic motivation toward programming, but boys were generally more motivated for programming than girls. High programming motivation was moderately related to teachers' higher CT instruction emphasis and students' higher CT test scores.

Conclusion: The findings give a strong incentive to pay attention to increasing especially girls' programming motivation and providing teachers with positive

CT experiences relevant to their subject and with a particular objective to increase intrinsic motivation especially among teachers who lack prior programming teaching experience and interest in the topic.

KEYWORDS

computational thinking, programming, intrinsic motivation, extrinsic motivation, teachers, students, basic education, ICILS

Introduction

Research concerning the teaching and learning of topics revolving around computing education has grown rapidly during recent years at various educational levels (Saqr et al., 2021). A key term placed at the center of several educational initiatives is *computational thinking* (CT); a competence, which encompasses skills to solve real-world problems with computational tools and methods and which all students are expected to acquire to prepare for subsequent studies and working life in the 21st century (Wing, 2006, 2011). The concrete activity of computer programming has become the most widely employed practical context to teach and learn CT in schools (Heintz et al., 2016). Notably, in Finland, CT was introduced centrally to all teachers in basic education by incorporating programming into the national core curriculum in 2014 (see Finnish National Agency of Education, 2016).

In 2018, a prominent international large-scale assessment of CT called the International Computer and Information Literacy Study (ICILS) was employed to measure Grade 8 students' CT skills and to examine home and school environments where their CT learning takes place. The results revealed substantial individual variation in students' CT skills, but only small variation between schools (Fraillon et al., 2019a; Leino et al., 2019). Students' high proficiency in CT was also related to higher home socioeconomic statuses and non-immigrant backgrounds. In turn, teachers across countries and schools varied in the extent to which they emphasized CT in their instruction. In other studies, Finnish teachers with certain profiles (namely, young male teachers) have also been noted to emphasize programming in their teaching more than other teachers (Kaarakainen et al., 2017). Hämäläinen et al. (2021) also found that older teachers tend to feel less prepared to use information and communications technology (ICT) in their teaching despite perceiving it as important, while some teachers seemed to think that ICT-related skills were not relevant to their subject.

The current Finnish basic education core curriculum was implemented gradually as of 2016. In the curriculum, programming is a key content for Grades 7–9 in a transversal competence called "ICT competence" that should penetrate all subjects (Finnish National Agency of Education, 2016, p. 304). It additionally has more detailed content and learning objective depictions in the subjects of mathematics (pp. 403, 408) and crafts (p. 463). However, the introduction of CT and programming through the curricular reform occurred "top-down" without being accompanied by centrally organized teacher trainings. Parallelly, teachers in Finland have much autonomy to decide the exact contents of their instruction as far as they do not conflict with the national core curriculum guidelines (Finnish National Agency of Education, 2018). It is then possible that individual teachers with higher affinity for ICT and programming became more active enactors of CT education. This conjecture can be traced to the theoretical domain of different types of motivation, which have long been recognized as fundamental factors influencing peoples' behavior (see e.g., Deci and Ryan, 1985). In education, high autonomous teaching motivation has been shown to predict teachers' more active participation in professional training and more active implementation of instructional innovations. Active participation in training and high quality of instruction, in turn, promotes students' learning outcomes (Gorozidis and Papaioannou, 2014). Although teaching and learning practices in schools can naturally be regulated by such key factors as teacher's expectations and knowledge (Kong et al., 2020), available resources (Weintrop et al., 2019), and available time for pedagogical planning (Waite et al., 2020), Finnish students' exposure to CT in basic education may have relied partly on the efforts of teachers who have been motivated for programming. It is possible that such teachers are especially those who teach "STEAM" (Science, Technology, Engineering, Arts, Mathematics) subjects, which have been traditionally affiliated with CT and programming education (see e.g., Mäkitalo et al., 2019). Relatedly, as Kirschner (2015) has also pointed out, the targeted use of technology by teachers requires not only devices but also knowledge, skills, and attitude.

In the present study, programming motivation is conceptualized through the self-determination theory (SDT; Deci and Ryan, 1985; Ryan and Deci, 2017) where different types of motivation are described in terms of the extent to which they represent autonomous versus controlled regulations. Two forms of programming motivation are investigated: (1) interest/enjoyment, referring to intrinsic motivation, and

(2) perceived value/usefulness, which can be understood as so-called identified motivation that is one form of extrinsic motivation (see Ryan and Deci, 2017). Intrinsically motivated behaviors are autonomous and performing out of pure interest and enjoyment. For instance, students who are intrinsically motivated for programming more likely seek further programming opportunities as they enjoy the activity. Correspondently, students have been previously found to gain a part of their digital skills in their free time (Vainikainen et al., 2022). In turn, regardless of personal interest or passion, extrinsic motivation refers to behaviors that are instrumental for other consequences, such as an external reward, social approval, avoidance of punishment, or the attainment of valued outcome (Ryan and Deci, 2000, 2017). One form of extrinsic motivation can be seen when a person is experiencing identified motivation as the behavior yields outcomes that are personally valued or important and congruent with one's values and beliefs (Sheldon and Elliot, 1998; Vasalampi et al., 2012). In programming, extrinsic motivation can be understood to affiliate more closely with the perceived educational relevance of programming, for instance, next to expectations of future careers (Kong et al., 2018) or, from the viewpoint of teaching, for enhancing instructional methods or students' skills instrumentally (Yukselturk and Altiok, 2017). It is important to note, though, that programming motivation may be shaped by understanding gained from actual prior programming experience (see e.g., Erol and Kurt, 2017) or more strongly by mere preconceptions if no clear understanding of what the activity entails has developed due to lack of prior experience (Mannila et al., 2020).

Although there are several studies about, for instance, teachers' and students' programming "attitudes," "beliefs," and "opinions," which may include connections to the theoretical constructs in motivation, only few studies have investigated teachers' and students' programming motivation explicitly let alone considered the potential role of prior programming teaching/learning experience in it. Therefore, according to our knowledge, only little is known about the extents of teachers' and students' intrinsic and extrinsic programming motivation and related antecedents. Prior research is also lacking regarding associations between programming motivation and teachers' CT instruction emphasis and students' CT proficiency. Altogether, especially prior programming experience likely plays a key role in programming motivation. Shedding further light on these issues is important to better understand the role of motivation in educational practice and how it could be better taken into consideration in teacher training and pedagogical planning in the future. Therefore, in this study, nationally comprehensive data collected in Finland for ICILS 2018 concerning Grade 8 teachers' and students' programming motivation is utilized to answer the following research questions (RQs):

1. How do teachers' and students' responses to intrinsic and extrinsic programming teaching/learning motivation questions distribute

- 1.1 For teachers?
- 1.2 For students?

2. When considering teachers' prior experience in teaching programming

- 2.1 How do teachers' intrinsic and extrinsic programming motivation differ?
- 2.2 To what extent does intrinsic and extrinsic programming motivation relate to subject taught, gender, and age?
- 2.3 To what extent does intrinsic and extrinsic programming motivation relate to teachers' CT instruction emphasis?

3. When considering students' prior experience in learning programming

- 3.1 How do students' intrinsic and extrinsic programming motivation differ?
- 3.2 To what extent does intrinsic and extrinsic programming motivation relate to students' gender and home socioeconomic background?
- 3.3 To what extent does intrinsic and extrinsic programming motivation relate to students' CT test scores?

Conceptual background and related work

Computational thinking and programming

Jeannette Wing (2006, 2011) opened the field of CT by inaugurating the term on a conceptual level and defining it as the "thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can effectively be carried out by an information-processing agent." Since then, there have been multiple efforts attempting to encapsulate the theoretical and operational underpinnings of the ill-established term. Currently, CT is widely understood as a competence that builds on the disciplinary notions in computing and the power of modern digital computer devices while solving problems in the real world (Denning and Tedre, 2019). Although such conceptual ideas have been recently framed specifically in CT, they have been taught, learned, and studied in schools and in the field of computing education for decades (see e.g., Pea et al., 1987) and, in a broader sense, long before modern digital devices had been invented (Tedre and Denning, 2016).

In the light of this framing for CT, there have been various scholarly efforts shaping the core CT skills and areas of knowledge that teachers should teach and students should learn in basic education today. Recent studies have begun distinguishing a "multiliteracy" dimension in CT by expanding it with sociocultural approach (Kafai et al., 2019; Mertala, 2021) and encompassing such pedagogical notions as relating to designing with technology on a personal level and critically reflecting the societal impact of contemporary computational technologies (Høholt et al., 2021). Despite this nascent but educationally meaningful viewpoint, the "problem-solving" dimension in CT has been generally more prevalent, portraying how CT can provide skills to understand and solve concrete real-life problems with computational methods. This dimension has been characterized with such core concepts and practices as abstraction, decomposition, algorithms, evaluation, and generalization that students are expected to learn (Barr and Stephenson, 2011; Grover and Pea, 2013; Shute et al., 2017). Establishing on this dimension, the theoretical definition of CT in ICILS 2018 (Fraillon et al., 2019b, pp. 27–28) involves two "strands," that is, conceptual categories framing its core skills and knowledge, and five more specific "aspects," that is, content categories for the two strands (see **Figure 1**).

The core conceptual and practical principles of CT are generally introduced to students through computer programming in teaching and learning practice in basic education (Grover and Pea, 2013). Nonetheless, CT and programming are not synonyms: programming is a concrete hands-on activity that can foster the more generic CT skills that go beyond mere programming knowledge and transfer across computational problem-solving domains (e.g., tools used to design computational solutions) (Tang et al., 2020). Cognitive underpinnings involved with CT are thus relevant beyond mere programming contexts (Wing, 2006) and have been portrayed in the context of various school subjects as well (see e.g., Settle and Perković, 2010; Moreno-León et al., 2017).

Educational programming tasks and activities for CT typically involve a real-world computational problem that students need to understand and analyze and subsequently solve or meet by designing a computational solution, such as an algorithm implemented with computer code. Although a CT methodology focused on data-driven machine learning is currently rising (see e.g., Vartiainen et al., 2020), the solutions—and thus views of CT—have commonly followed the traditional "step-by-step" algorithmic computing methodology. Several educational programming environments that build upon this methodology are easy to access and use for both teachers and students: they emphasize learner-centered learning that is expected to capture the interest of students and engage them in learning, which lowers the threshold to include them in teaching and learning activities (Lye and Koh, 2014). Popular approaches include a variety of block-based programming or "coding" environments on the web, such as Scratch, purchasable programming tools and kits, such as Lego robotics and Micro:bits, and text-based programming languages, such as Python and JavaScript (Garneli et al., 2015). The manifold programming environments, tools, and languages are used in more drill-like exercises, such as those presented in (Lambić et al., 2021), and more learner-centered, creative craft-like projects in which students can more broadly apply their creativity and interest areas (Brennan and Resnick, 2012).

Teachers' programming motivation

The scarce prior empirical studies on teachers' programming motivation have focused mainly on pre-service teachers and computer science (CS) or information technology (IT) teachers likely because programming and CT are relatively new cross-curricular contents in basic education. As expected, pre-service CS teachers have had moderately positive attitudes toward programming and moderately high self-efficacy in programming, which has also correlated with their achievement in programming-themed training courses (Gurer et al., 2019). Otherwise, there have been preliminary findings showing that basic education teachers on average consider training programming to be difficult and may lack understanding regarding the purpose of programming education (Hartell et al., 2019). Concurrently, some teachers have been noted to disapprove programming curricula (Mühling et al., 2010). Teachers' comfort levels to teach programming, create CT teaching materials, and integrate CT in their lessons have also varied widely, suggesting that some teachers may not be well prepared to integrate CT in their teaching (Garvin et al., 2019).

Several studies have investigated teachers' motivation-related aspects in specific educational programming contexts. Notably, gaining hands-on experience of programming has been shown to increase positive attitudes and negate initial gender differences in attitudes between pre-service IT teachers (Erol and Kurt, 2017). Gaining programming experience has also improved pre-service teachers' attitudes toward programming and utilizing ICT generally in teaching (Fesakis and Serafeim, 2009). Similarly, in Yukselturk and Altiok's (2017) study, pre-service teachers' enjoyment of programming (an aspect of intrinsic programming motivation) and self-efficacy increased whereas their fear of programming decreased after attending a Scratch programming course. However, their attitudes toward the value and importance of learning programming (an aspect of extrinsic programming

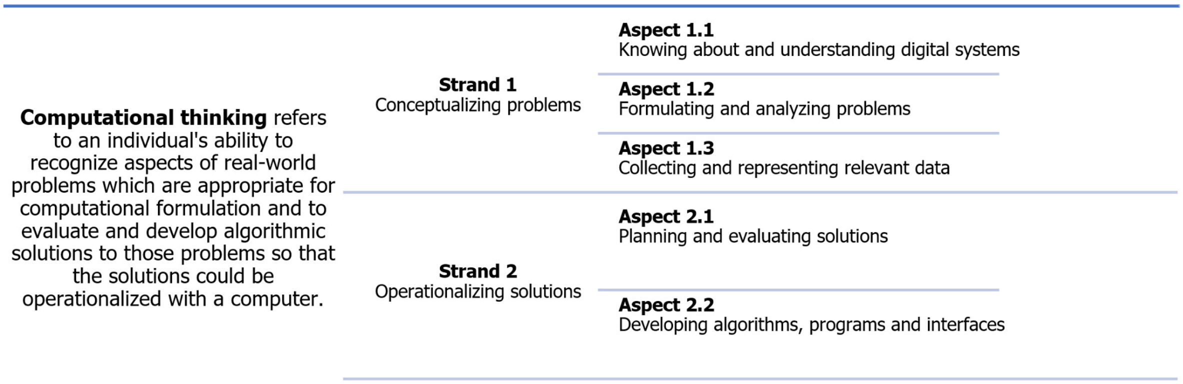

FIGURE 1
The CT framework in ICILS 2018 (see Fraillon et al., 2019b, pp. 27–28).

motivation) did not increase. Choi's (2013) study demonstrated a similar change: pre-service teachers' initial thoughts on programming being, for instance, difficult, scary, and perplexing changed to a level of enjoyment, accomplishment, and confidence after gaining programming experience. However, teachers have been shown to have positive attitudes especially toward specific pedagogical solutions (e.g., lesson structure plans) in programming education (Sentance et al., 2019), suggesting that the nature of the manifold CT contents being adopted by teachers are important to consider. Similarly, CT has been shown to include specific substances that can be stronger causes of uncertainty for teachers (Rich et al., 2021).

Students' programming motivation

Compared to scarce previous research on teachers' programming motivation, several previous studies have examined motivation and attitudes toward programming-related topics among students of different ages and with different backgrounds. Notably, Sun et al. (2022) recently found that Chinese Grade 7 students' high programming interest (an aspect of intrinsic motivation) was related to better CT learning outcomes. The study also found that girls had on average higher CT proficiency than boys but more negative programming attitudes, including interest. Other studies have also provided evidence that boys have more positive attitudes toward programming-related topics than girls (Mahoney, 2010; Kier et al., 2014; Gunbatar and Karalar, 2018; Kong et al., 2018), corresponding with the common view of computing-related studies and work fields being male-dominant. However, other studies (Mason and Rich, 2020; Gul et al., 2021) have not found gender differences in students' programming attitudes, and gender differences have also been shown to disappear in some studies after gaining programming experiences (Gunbatar and Karalar, 2018). On another note, results regarding the role of gender in the level of students' CT proficiency have also varied: in ICILS 2018 (Fraillon et al., 2019a), the average CT proficiency in all participating countries was in favor of boys. However, statistically significant differences were found only in two countries: in favor of boys in Portugal and of girls in Finland. Then again, another Finnish study (Vainikainen et al., 2022) found that boys had higher programming proficiency than girls.

Previous studies have discovered that students' programming motivation associates with such factors as ethnicity, grade level, coding frequency, and math interest (Mason and Rich, 2020; Gul et al., 2021). Although social factors, such as home socioeconomic background, have been positively related to students' better performance in CT tasks (Fraillon et al., 2019a), their role in programming attitudes has been so far inconclusive (see Mannila et al., 2020; Mason and Rich, 2020). However, as with teachers, gaining actual programming experiences has been shown to promote students' positive programming attitudes, including their interest (Sun et al., 2022). The main reason is likely that programming with contemporary tools is generally designed to be motivating for students in different educational levels and in different contexts (Garneli et al., 2015). Several context-specific studies (e.g., Ruf et al., 2014; Asad et al., 2016; Jiang and Wong, 2017; Lambić et al., 2021; Tisza and Markopoulos, 2021) have illustrated in practice how students' attitudes toward programming can increase after programming with a variety of tools and while participating in collaborative, engaging, and appropriately challenging and interesting coding tasks (see Lye and Koh, 2014; Dohn, 2019; Sharma et al., 2019). Connectedly, the number of years of programming learning has been shown to positively relate to students' programming attitudes (Sun et al., 2022), demonstrating the importance of sustained exposure to programming rather than gaining singular introductions to only specific ways of programming, such as the popular "Hour of Code" (see also Mason and Rich, 2020).

Materials and methods

Participants and data collection

International Computer and Information Literacy Study is an international study organized by International Association for the Evaluation of Educational Achievement (IEA) in partnership with Australian Council for Educational Research and national research centers of participating countries in 2013 and 2018. ICILS 2018 (Fraillon et al., 2019a, pp. 9–10) gathered data of Grade 8 students' computer and information literacy (CIL) proficiency from 12 countries and two benchmarking areas as well as their CT proficiency as an optional assessment from eight countries and one benchmarking area. In addition to assessing students' skills and knowledge, contextual questionnaires were presented for students, teachers, school ICT coordinators, principals, and national research centers. The tests and surveys were conducted on computers.

In the present study, we utilize student and teacher data collected in ICILS 2018 in Finland. The sampling design (see Fraillon et al., 2020) involved multi-stage sampling, stratification, and cluster sampling. The sampling of students and teachers specifically was a two-stage cluster sampling (see also Fraillon et al., 2019a, p. 11). In Finland, first, 150 schools with the target grade students were randomly selected with a probability proportional to size and utilizing the NUTS classification (see Statistics Finland, 2022) for regions. Second, 20 Grade 8 students (or all students if less than 25 students were enrolled in the grade) were randomly sampled in each sampled school. Additionally, 15 teachers that taught Grade 8 students at the time of testing (or all teachers if less than 20 Grade 8 teachers worked in the school) were randomly sampled in each sampled school. The sampled teachers taught different subjects, and the sampling did not consider if a teacher had taught any of the sampled students or not. The final national data in Finland concluded 2,546 students and 1,853 teachers from 145 schools.

Teacher measures

Teachers in ICILS 2018 responded to a questionnaire enquiring about their perceptions and use of ICT and various background variables. In the present study, the examined background variables were gender (binary), age, subjects taught, and previous programming teaching experience (yes/no). Teachers' CT instruction emphasis was assessed in the questionnaire with a question enquiring how much in their teaching of the reference class[1] during the current school year they emphasized the given CT skills (see items in **Table 1**). The response options were presented on a 4-point Likert scale (1 = strong emphasis, 2 = some emphasis, 3 = little emphasis, 4 = no emphasis). Items A to I were international items and items J to M nationally added items that were more contextualized to programming.

Teachers' programming motivation was assessed in a separate question using two subscales utilized from the Intrinsic Motivation Inventory (IMI[2]; for validity, see McAuley et al., 1987): (1) interest/enjoyment (items A to C in **Table 2**, Cronbach's α = 0.81) and (2) value/usefulness (items D to F, Cronbach's α = 0.82). The interest/enjoyment subscale measures

1 In ICILS 2018, teachers were instructed to select their reference class that is the first Grade 8 class that they taught for a regular subject (i.e., other than home room and assembly) on or after Tuesday following the last weekend before they first accessed the questionnaire.

2 Intrinsic Motivation Inventory is a psychometric tool to evaluate research participants' subjective experience, such as interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice related to a target activity. The inventory can be modified to include or exclude subscales without significant impact, resulting in a chosen selection of subscales relevant to the investigation. The inventory can be attained from: https://selfdeterminationtheory.org/intrinsic-motivation-inventory/.

TABLE 1 Question items for teachers' CT instruction emphasis in ICILS 2018 in Finland.

Item	
International items	
A.	To display information in different ways
B.	To break a complex process into smaller parts
C.	To understand diagrams that describe or show real-world problems
D.	To plan tasks by setting out the steps needed to complete them
E.	To use tools making diagrams that help solve problems
F.	To use simulations to help understand or solve real-world problems
G.	To make flow diagrams to show the different parts of a process
H.	To record and evaluate data to understand and solve a problem
I.	To use real-world data to review and revise solutions to problems
National items	
J.	To interpret and create algorithms, that is, detailed instructions
K.	To program computer programs
L.	To understand and apply programming language constructs (e.g., loop, conditional structure, and variable)
M.	To understand and apply good programming practices (e.g., planning, debugging, and evaluation)

teachers' intrinsic motivation, whereas the value/usefulness subscale measures teachers' identified motivation (see also McAuley et al., 1987; Deci et al., 1994), that is, one form of extrinsic motivation. Teachers were asked, "When thinking about your relationship toward programming and [teaching/considering teaching] it, to what extent do you agree or disagree with the following statements?" As demonstrated with the square brackets, the subscales had two slightly different but construct-wise not dissimilar formats for teachers who responded "yes" or "no" to a previous question regarding whether they had prior experience in teaching programming. The response options were presented on a 4-point Likert scale (1 = completely disagree, 2 = disagree, 3 = agree, 4 = completely agree). The two subscales correlated moderately positively both for teachers with prior experience in teaching programming (r = 0.37, SE 0.07) and those without it (r = 0.44, SE 0.02). Teachers who answered the questionnaire also selected different subjects (one or more) that they taught for at least four lessons each week in the school in the school year (see **Table 3**).

Student measures

In Finland, each sampled student in ICILS 2018 completed two of a total of five randomly selected 30-min CIL modules and two 25-min CT modules that were the same for all students (Fraillon et al., 2019a, pp. 8–9). Both CT modules had several problem-solving tasks with a unifying theme, and they were designed to measure the aspects presented in **Figure 1**. We used students' CT task scores, which are based on five different plausible values. The analyses are performed for the each plausible value separately after which their average is used (see Fraillon et al., 2020, pp. 152–153, 224). The task scores from all the CT tasks were aggregated to establish a total CT test score with a standardized international mean score of 500 and a standard deviation of 100 (Fraillon et al., 2019a, p. 92).

Between the CIL and CT modules, the students completed a questionnaire enquiring their learning about ICT, CIL, and CT and various background variables. In the present study, the examined background variables were gender (binary), prior programming experience (yes/no), and home socioeconomic background, which was combined from the parents' highest level of education, parents' highest occupation based on the International Standard Classification of Occupations, and the amount of books at home (see Fraillon et al., 2019b, p. 40).

Students' programming motivation was assessed in the questionnaire using the same two subscales utilized from the IMI as with the teachers. The students were asked, "When thinking about your relationship toward programming and [studying/considering studying] it, to what extent do you agree or disagree with the following statements?" The subscales were similarly those of (1) interest/enjoyment (items A to C in **Table 4**, Cronbach's α = 0.88) and (2) value/usefulness (items D and E, Cronbach's α = 0.76). The interest/enjoyment subscale measured students' intrinsic motivation, whereas the value/usefulness subscale measured their identified motivation (see also McAuley et al., 1987; Deci et al., 1994), that is, one form of extrinsic motivation. Both aspects of programming motivation were measured using a 4-point Likert scale (1 = completely disagree, 2 = disagree, 3 = agree, 4 = completely agree), and, as demonstrated by the square brackets, the questions had two slightly different but construct-wise not dissimilar formats for students with and without prior experience in programming. The two examined types of motivations correlated moderately positively both for students with prior experience in programming (r = 0.53, SE 0.03) and those without it (r = 0.58, SE 0.02).

TABLE 2 Items for the question concerning teachers' programming motivation in ICILS 2018 in Finland.

Subscale		Item
Intrinsic motivation	A.	Programming [is/seems] very interesting.
	B.	[I teach/If given an opportunity, I would teach] programming gladly.
	C.	[I do/I could imagine myself doing] computer programming in my leisure time.
Extrinsic motivation	D.	It is important to learn to understand the principles of programming in today's society.
	E.	It is important to learn how to program computer programs in today's society.
	F.	Studying programming benefits the students in their other studies and in working life.

Data analysis

As the ICILS 2018 sample is not based on simple random sampling, the generalization of the results to the target population is not straightforward. The complex sampling design and the non-participation of schools, students, or teachers could lead to biased results if the data was treated as if it was drawn from a simple random sample. To achieve unbiased estimates of the corresponding population, sampling weights and non-response adjustments for each school were used when analyzing the data (Fraillon et al., 2020, p. 79). When estimating the variances and standard errors for the population statistics, jackknife repeated replication technique was used (see also Fraillon et al., 2020, p. 221).

For RQ1, descriptive statistics of the students' and teachers' responses to the programming motivation

TABLE 3 Subjects taught by the respondent teachers with and without prior experience in teaching programming.

Subject	Teachers with prior experience in teaching programming		Teachers without prior experience in teaching programming		Total
	N	% of total	*N*	% of total	
Mother tongue I.e., Finnish/Swedish and literature or Finnish/Swedish as second language for other language groups	44	13.3	286	86.7	330
Foreign languages I.e., second national language, English, and other languages	26	6.1	400	93.9	426
Mathematics	290	63.7	165	36.3	455
Sciences I.e., physics, chemistry, biology, and geology/geography	220	49.2	227	50.8	447
Human sciences or social studies History, social studies, law, economics, etc.	19	8.9	195	91.1	214
Creative arts Visual arts, music, dance, drama, etc.	36	19.9	145	80.1	181
IT, programming, or similar	77	91.7	7	8.3	84
Practical and vocational subjects E.g., crafts	71	37.8	117	62.2	188
Other E.g., life philosophy, physical education, home economics, health education, and student counseling	49	10.6	415	89.4	464

A teacher can have chosen several subjects, and therefore the number of teachers does not correspond to the number of respondents.

questions were explored. For RQs 2.1 and 2.2, teachers' gender age, and subjects taught were set as explanatory variables, and the effect of those variables on the subscales of intrinsic and extrinsic motivation were analyzed by examining (weighted) mean differences and by linear regression. Similar analyses to explore the effects on the two motivation subscales were performed for students (RQs 3.1 and 3.2) using gender and home socioeconomic background as explanatory variables. The analyses for gender, age, and home socioeconomic background were performed separately for teachers and students with and without prior programming teaching/learning experience to examine differences between these two experience groups. This approach was chosen instead on just one regression analysis in which some connections were not visible and also because the motivation questions for the two experience groups were slightly different (see **Tables 2**, **4**). Correlation coefficients between the subscales were examined using Pearson correlation coefficient. For RQs 2.3 and 3.3, regression analyses were performed for the scales of interest, that is, CT instruction emphasis for teachers (see also Fraillon et al., 2020, p. 191) and CT test scores for students separately for teachers and students with and without prior programming teaching/learning experience.

TABLE 4 Items for the question concerning students' programming motivation in ICILS 2018 in Finland.

Subscale	Item	
Intrinsic motivation	A.	Programming [is/seems] very interesting.
	B.	[I study/If given an opportunity, I would study] programming gladly.
	C.	[I do/I could imagine myself doing] computer programming in my leisure time.
Extrinsic motivation	D.	It is important to learn to understand the principles of programming in today's society.
	E.	Studying programming [benefits/would benefit] my learning in other studies or my working life.

Statistical significances of the mean differences and regression coefficients were also obtained. The significances are based on observed *t*-values, which were compared to the critical values of the standard normal distribution. This is a standard procedure in large scale assessments and is based on large sample size and the asymptotic normality of estimators. In the regression analyses, no multicollinearity issues were observed. All analyses were performed with the IEA IDB Analyzer data analysis software.

Results

Teachers' programming motivation

Teachers' responses to programming motivation questions (research question 1.1)

Descriptive statistics of the teachers' responses to the programming motivation question items are shown in Table 5. On average, teachers agreed with the statements in favor of their extrinsic programming motivation and especially about the importance of learning to understand the principles of programming in today's society and its benefits for the students' other studies and working life. However, they disagreed more with the intrinsic motivation statements. For example, most of the teachers did not or could not imagine themselves doing programming in their leisure time, although more than half of the teachers considered programming interesting, and nearly half of the teachers taught or would have liked to have taught programming gladly.

Teachers' background and programming motivation (research questions 2.1 and 2.2)

Our next RQs concerned how teachers' prior programming teaching experience, gender, subject taught, and age are related to their programming motivation. These RQs were examined by exploring (weighted) mean differences and linear regression analysis.

Teachers with prior experience in teaching programming had substantially higher intrinsic motivation than teachers without said experience (Mean = 2.63 cf. 1.79; difference 0.83, SE 0.04, $p < 0.001$, Cohen's $d = 1.34$). In turn, extrinsic programming motivation was only slightly higher among teachers with prior experience in teaching programming (Mean = 2.82 cf. 2.68; difference 0.14, SE 0.04, $p < 0.001$, Cohen's $d = 0.24$). Statistically significant gender differences did not emerge in teachers' extrinsic programming motivation in either experience group, but such differences were found in intrinsic motivation among both groups (see Table 6). Male teachers generally reporting a higher level of intrinsic motivation than female teachers. Intrinsic motivation among male teachers with prior programming teaching experience situated on the positive side of the 4-point Likert scale (2.5) whereas among female teachers the average was in the middle (difference −0.15, SE 0.06, $p < 0.05$, Cohen's $d = 0.26$). Gender differences among teachers without prior programming teaching experience followed a similar pattern (difference −0.22, SE 0.04, $p < 0.001$, Cohen's $d = 0.35$), but the average values were comparably much lower and on the negative side of the scale. In contrast, both experience groups' average extrinsic programming motivation leaned toward the positive side of the scale.

The subjects that the teachers taught were related to the teachers' intrinsic and extrinsic motivation statistically significantly (see Table 7). Specifically, teachers' intrinsic programming motivation was higher if the teacher taught IT-related subjects, mathematics, practical and vocational subjects, and creative arts. In turn, teachers' intrinsic motivation was lower if they taught national or foreign languages, subjects in the aggregated category of "other subjects," and human sciences or social studies. Higher extrinsic motivation related only to teaching IT-related subjects, and, for lower extrinsic motivation, teaching foreign languages.

Teacher's age was weakly but statistically significantly related only to intrinsic motivation (but not extrinsic motivation) at the $p < 0.05$ level. Among teachers with prior experience in teaching programming, the regression coefficient was 0.01, denoting that intrinsic motivation was slightly higher among teachers in this experience group that were older than the average age of the respondents. Among teachers without prior experience in

TABLE 5 Descriptive statistics of teachers' programming motivation.

Subscale		Item	Percentage distributions of responses			
			1 – completely disagree (%)	2 – disagree (%)	3 – agree (%)	4 – completely agree (%)
Intrinsic motivation	A.	Programming [is/seems] very interesting.	13.3	28.2	43.1	15.5
	B.	[I teach/If given an opportunity, I would teach] programming gladly.	20.9	33.1	35.8	10.3
	C.	[I do/I could imagine myself doing] computer programming in my leisure time.	50.2	36.6	10.3	3.0
Extrinsic motivation	D.	It is important to learn to understand the principles of programming in today's society.	4.5	17.8	63.8	14.1
	E.	It is important to learn how to program computer programs in today's society.	8.0	43.9	42.5	5.7
	F.	Studying programming benefits the students in their other studies and in working life.	3.0	13.5	71.3	12.3

TABLE 6 Means and standard deviations, mean differences, and effect sizes (Cohen's *d*) of intrinsic and extrinsic motivation among the teacher respondents by gender and separately for teachers with and without programming experience.

	Teachers with prior experience in teaching programming		Teachers without prior experience in teaching programming	
	M	SD	*M*	SD
Intrinsic motivation				
Female	2.55	0.62	1.74	0.59
Male	2.71	0.65	1.96	0.65
Difference	−0.15		−0.22	
Cohen's *d*	0.26		0.35	
Extrinsic motivation				
Female	2.82	0.52	2.68	0.58
Male	2.82	0.59	2.69	0.60
Difference	0.00		−0.01	
Cohen's *d*	0.00		0.02	

The values are situated on a 4-point Likert scale.

TABLE 7 Estimates (and standard errors) for regression coefficients in teachers' intrinsic and extrinsic motivation by subjects taught, gender, and age.

	Intrinsic motivation		Extrinsic motivation	
	b (SE)	β (SE)	*b* (SE)	β (SE)
Subject				
Mother tongue	−0.14 (0.05)**	−0.07 (0.03)**	−0.02 (0.05)	−0.01 (0.03)
Foreign languages	−0.22 (0.05)***	−0.13 (0.03)***	−0.15 (0.04)***	−0.11 (0.03)***
Mathematics	0.44 (0.05)***	0.27 (0.03)***	0.06 (0.04)	0.05 (0.03)
Sciences	0.02 (0.05)	0.01 (0.03)	−0.05 (0.05)	−0.04 (0.04)
Human sciences or social studies	−0.12 (0.05)*	−0.06 (0.02)*	0.00 (0.05)	0.00 (0.02)
Creative arts	0.16 (0.06)*	0.07 (0.03)*	0.01 (0.06)	0.00 (0.03)
IT, programming, or similar	0.63 (0.09)***	0.18 (0.02)***	0.27 (0.05)***	0.10 (0.02)***
Practical and vocational subjects	0.25 (0.06)***	0.10 (0.02)***	0.02 (0.06)	0.01 (0.03)
Other	−0.13 (0.04)**	−0.08 (0.03)**	−0.01 (0.04)	−0.01 (0.03)
Gender(male)	0.18 (0.03)***	0.11 (0.02)***	−0.02 (0.03)	−0.01 (0.02)
Age	−0.01 (0.00)***	−0.09 (0.02)***	0.00 (0.00)	−0.01 (0.02)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. *b* = unstandardized β; β = standardized β; SE = standard error.

teaching programming, the coefficient was −0.01, SE = 0.00, β = −0.09, SE (β) = 0.03, $p < 0.01$, showing an inverted effect.

Teachers' computational thinking instruction and programming motivation (research questions 2.3)

Research questions 2.3 concerned associations between teachers' intrinsic and extrinsic programming motivation and their CT instruction emphasis. Regression analysis showed that high intrinsic motivation related to higher instruction emphasis in the international CT-focused item scale (items A to I in Table 1) among both teachers with prior programming teaching experience [regression coefficient b = 0.14, SE (b) = 0.04, β = 0.14, SE (β) = 0.04] and those without it [b = 0.18, SE (b) = 0.03, β = 0.17. SE (β) = 0.03, $p < 0.001$]. A similar effect was shown in instruction emphasis in the more programming-specific item scale (J to M), where, next to the CT items, the effect was slightly stronger among teachers with prior programming teaching experience [b = 0.30, SE (b) = 0.06, β = 0.27, SE (β) = 0.05, $p < 0.001$] and approximately the same among teachers without said experience [b = 0.13, SE (b) = 0.03, β = 0.16, SE (β) = 0.03, $p < 0.001$]. Although the coefficients were relatively modest, they revealed that there altogether were general positive trends.

Extrinsic programming motivation had no statistically significant effects on either CT or programming instruction among teachers with prior programming teaching experience. However, a very weak negative effect emerged among programming-wise inexperienced teachers' emphasis on the programming-specific items [b = −0.06, SE (b) = 0.02, β = −0.07, SE (β) = 0.03, $p < 0.01$].

Students' programming motivation

Students' responses to programming motivation questions (research question 1.2)

Descriptive statistics of the students' responses to the programming motivation questions are shown in Table 8. More than two thirds of the students agreed or completely agreed with the statements in favor of their extrinsic programming motivation. In contrast, more students disagreed more with the intrinsic motivation statements, even though more than half of the students nonetheless perceived programming as interesting and studied it or would have liked to have studied it gladly. However, most of the students did or could not imagine themselves doing programming in their leisure time.

Students' background and programming motivation (research questions 3.1 and 3.2)

Research questions 3.1 and 3.2 concerned how prior programming experience, gender, and home socioeconomic background are related to students' programming motivation. These RQs were examined by exploring (weighted) mean differences and linear regression analysis.

Students with prior programming experience had on average slightly higher intrinsic (Mean = 2.60 cf. 2.26; difference 0.34, SE 0.04, $p < 0.001$, Cohen's d = 0.45) and extrinsic (Mean = 2.90 cf. 2.66; difference 0.24, SE 0.03, $p < 0.001$, Cohen's d = 0.36) programming motivation than students without said experience. In terms of gender, statistically significant differences among the students' programming motivation levels were found in both experience groups (see Table 9). Specifically, boys had on average high intrinsic motivation, and it was much higher than girls' intrinsic motivation among both students with prior programming experience (difference −0.46, SE 0.06, $p < 0.001$, Cohen's d = 0.67) and those without it (difference −0.47, SE 0.05, $p < 0.001$, Cohen's d = 0.65). Girls' intrinsic motivation leaned slightly to the negative side of the scale midpoint (2.5). Gender differences in extrinsic motivation followed a similar pattern with the exception that the averages were slightly higher.

Home socioeconomic background was weakly but positively related only to extrinsic motivation (but not intrinsic motivation) among both for students with prior programming experience [b = 0.07, SE 0.03, β = 0.11, SE (β) = 0.04, $p < 0.01$] and those without it [b = 0.06, SE 0.01, β = 0.09, SE (β) = 0.02, $p < 0.001$].

Students' computational thinking test scores and programming motivation (research question 3.3)

Research question 3.3 concerned associations between the students' motivation and their CT test scores. According to our regression analysis, students' high intrinsic motivation was related to higher CT test scores only for students with prior programming experience [b = 12.95, SE = 5.55, β = 0.11, SE (β) = 0.05, $p < 0.05$]. In other words, a 1-point increase in the motivation item (Likert scale 1 to 4) raised the CT test score (Mean = 500, SD = 100) by 12.95 points among students in this experience group. High extrinsic motivation, in turn, was only related to higher CT test scores for students without programming experience [b = 10.88, SE = 4.55, β = 0.08, SE (β) = 0.03), $p < 0.05$]. Although the coefficients were relatively modest in both regressions, they revealed that there altogether were general positive trends.

TABLE 8 Descriptive statistics of students' programming motivation.

Subscale		Item	Percentage distributions of responses			
			1 – completely disagree (%)	2 – disagree (%)	3 – agree (%)	4 – completely agree (%)
Intrinsic motivation	A.	Programming [is/seems] very interesting.	10.2	32.2	39.2	18.5
	B.	[I study/If given an opportunity, I would study] programming gladly.	11.7	32.9	40.2	15.3
	C.	[I do/I could imagine myself doing] computer programming in my leisure time.	27.4	47.2	19.4	6.1
Extrinsic motivation	D.	It is important to learn to understand the principles of programming in today's society.	4.8	22.8	59.8	12.7
	E.	Studying programming [benefits/would benefit] my learning in other studies or my working life.	7.5	25.1	52.2	15.3

TABLE 9 Mean and standard deviations, mean differences, and effect sizes (Cohen's *d*) of intrinsic and extrinsic motivation among the student respondents by gender and separately for with and without programming experience.

	Students with prior experience in programming		Students without prior experience in programming	
	M	SD	*M*	SD
Intrinsic motivation				
Girl	2.28	0.69	2.07	0.70
Boy	2.75	0.72	2.55	0.78
Difference	−0.46		−0.47	
Cohen's *d*	0.67		0.65	
Extrinsic motivation				
Girl	2.79	0.63	2.63	0.68
Boy	2.94	0.66	2.71	0.70
Difference	−0.15		−0.09	
Cohen's *d*	0.23		0.12	

The values are situated on a 4-point Likert scale.

Discussion

Overview of the results

Main findings regarding teachers

Finnish teachers' generally high extrinsic programming motivation in terms of their perceived value and importance of programming corresponds with the broadly voiced educational importance of the topic and global initiatives surrounding its integration in school curricula (Heintz et al., 2016). In turn, teachers experienced relatively low intrinsic programming motivation as relatively few teachers welcomed the idea of programming in their free time. These results suggest that teachers may consider programming as an educationally important topic but not necessarily be very interested in it personally (see also Ryan and Deci, 2000, 2017). However, the substantial variability between teachers within both types of motivation displayed that there are teachers who are highly motivated for the topic. Similarly, as also preliminarily noted by Hartell et al. (2019), some teachers are evidently not convinced of the educational value of programming despite the prevalent view. Teachers' intrinsic and extrinsic programming motivation correlated moderately, though, suggesting that individual teachers' both types of motivation may be uniformly lower and higher rather than inclusive of a noticeable difference.

The results showed further that male teachers as well as teachers with prior experience in teaching programming were more motivated toward programming (especially intrinsically) than female teachers and teachers without prior programming teaching experience. In this respect, the results seem to explain the finding by Kaarakainen et al. (2017) stating that Finnish male teachers teach programming more often than female teachers. However, especially the effect of prior programming teaching experience was very large when compared to the other examined variables. Regarding age, younger teachers have been previously found to use ICT more in their teaching (Hämäläinen et al., 2021). However, our findings showed such a nuance that intrinsic programming motivation among teachers with prior experience in teaching programming was slightly higher the older the teacher was. One reason could be that teachers' programming motivation deepens along the years if they have already adopted the topic in their instructional practice. Younger teachers may also need to spend more time for managing basic teaching activities and be less able to adopt novel pedagogical dimensions.

Second, the subjects that the teachers taught also played a role in their programming motivation. Programming-wise the most motivated teachers were those who taught IT-related subjects, mathematics, practical and vocational subjects, and creative arts. Alongside the results gained by Gurer et al. (2019), the role of IT is unsurprising, because, in terms of the disciplinary backgrounds of CT and programming (see Denning and Tedre, 2019), these topics are the closest to IT among the subjects taught in Finnish basic education. Programming has also been taught at the basic education level before it has been enveloped in contemporary CT discourse (see e.g., Pea et al., 1987). In turn, the placement of programming in mathematics and practical and vocational subjects in the Finnish curriculum (Finnish National Agency of Education, 2016) could mainly explain the distinctive role of these subjects. A reason for creative arts teachers' higher programming motivation could be the focus on creative expression in animating with the popular programming tool Scratch (see Brennan and Resnick, 2012). In contrast, teachers who teach linguistic subjects, human sciences, social studies, and other subjects, such as physical education and health education as listed in **Table 3** may be more strangers to the problem-solving aspects of CT characteristic to activities (see **Figure 1**) typically present in STEAM subjects.

Teachers of humanities and social sciences could, however, find the multiliteracy aspects of CT (see e.g., Høholt et al., 2021) interesting and valuable, though. This speculation is reinforced with the fact that, in the present study, teachers generally agreed more for the statement that in today's society it is important to learn to understand the principles of programming rather than to learn to program computer programs.

Examination of the associations between teachers' programming motivation and their CT instruction emphasis suggested that especially intrinsic programming motivation may promote instructional emphasis on both the more cross-contextual CT skills and on skills more directly contextualized to programming. This suggested that motivation can play a role in teachers' adoption of CT altogether, which is likely encouraged by the large amount of teacher autonomy in Finnish basic education (see Finnish National Agency of Education, 2018). Although the direction of the relationship was not revealed directly, the data showed that intrinsic motivation was positively related especially to prior experience in teaching programming. Prior studies have also shown that gaining positive programming experiences improves teachers' attitudes toward programming (Fesakis and Serafeim, 2009; Choi, 2013; Erol and Kurt, 2017; Yukselturk and Altiok, 2017). It thus seems that positive personal programming experiences especially can spark motivation to adopt CT in instruction.

Main findings regarding students

Finnish Grade 8 students' average programming motivation on the positive side of the scales indicates that students largely consider programming as a personally interesting or enjoyable activity and generally as a valuable educational topic (see also Kong et al., 2018; Mason and Rich, 2020). It was especially interesting, however, that students had roughly the same amount of intrinsic and extrinsic programming motivation whereas teachers had relatively less intrinsic than extrinsic motivation. Students' programming motivation has likely been promoted by the development and dissemination of assorted age-appropriate educational programming environments (see Garneli et al., 2015). These findings are promising in the sense that, according to the SDT (Ryan and Deci, 2000, 2017), students can be expected to be resultantly engaged in learning CT. However, it is important to note that there was substantial variability in both types of programming motivations between students, and the motivation types also correlated moderately. Many students could therefore benefit from being more motivated in programming both intrinsically and extrinsically. However, as Mannila et al. (2020) have discussed, students without prior experience in programming may lack a clear understanding of what the activity entails and be unable to form informed attitudes toward it. Therefore, many students could most essentially benefit from broader awareness of what programming is.

With the above being said, the existence of prior programming experience as a background factor related positively to programming motivation, which is in line with numerous studies conducted in specific programming contexts (see e.g., Ruf et al., 2014; Asad et al., 2016; Jiang and Wong, 2017; Sharma et al., 2019; Lambić et al., 2021; Tisza and Markopoulos, 2021). The effect size was medium. Combined with the speculation regarding programming-wise inexperienced students' lack of understanding regarding what programming is, gaining hands-on programming experiences seems to demonstrate the nature, interestingness, and value of programming to students in practice potentially well. However, it is important to note that hands-on learning experiences can impact motivation negatively if care is not devoted to effective pedagogical design (see Dohn, 2019).

Second in terms of students' backgrounds, there were pronounced differences in programming motivation between girls and boys. As evinced also in prior research (Mahoney, 2010; Kier et al., 2014; Gunbatar and Karalar, 2018; Kong et al., 2018; Sun et al., 2022), boys are significantly more interested in programming-related topics than girls. Gender differences existed both in intrinsic and extrinsic motivation, and girls' average of extrinsic motivation on the negative side of the scale midpoint indicates that many Finnish girls do not value programming. This corresponds with the stereotypical view of computing-themed studies and work fields as male-dominant. However, gender differences have been seen to diminish after gaining programming experiences (Gunbatar and Karalar, 2018), which suggests that especially girls should have more positive programming experiences in the future.

Third, home socioeconomic background, which has previously been found to relate positively to students' CT learning outcomes (Fraillon et al., 2019a; Leino et al., 2019), also related positively to students' extrinsic programming motivation (but not intrinsic motivation), although this relationship was rather weak. This showed slight support for Mannila et al.'s (2020) speculation that family may play a role in a student's perception of the value or usefulness of programming. Parents can, for instance, have favor for studying ICT-related topics to prepare their child for societally valuable future careers. However, it seems that more essential factors reside elsewhere.

Our results regarding the associations between students' programming motivation and their CT test scores showed that high intrinsic programming motivation was related to higher CT skills among students with prior programming experience. High extrinsic motivation was also related to higher CT skills among students without programming experience. The relationship between motivation and CT learning in general was consistent with previous research (see Mason and Rich, 2020; Sun et al., 2022). Specifically, intrinsically motivated students with prior programming experience may have performed better because they may have had voluntarily sought out additional learning situations (see Ryan and Connell, 1989). This point would also support the finding by Vainikainen et al. (2022) that Finnish students acquire a share of their digital skills through learning that is guided by their interest, and that digital skills are generally higher among students who volitionally engage in digital activities more often. In turn, students with high extrinsic programming motivation without prior programming experience may have put more effort in the CT test in ICILS for valuing the topic more than those with low extrinsic motivation. The regression coefficients were not overly large, though, which could be partly explained by the timing of the data collection: the students may have had only little prior exposure to CT, because programming was introduced to the population via the core curriculum the following academic year after the ICILS assessment.

Implications for practice and future research

The broader adoption of CT in basic education could be aided by guiding all teachers to integrate CT in teaching through clear curricular guidelines. Effective implementation of such guidelines would naturally necessitate systematic training, which has been previously lacking in Finland. Because teachers have much autonomy, it is important to promote especially their intrinsic programming motivation, which appears meaningful for adopting CT in instruction and currently varied in the population. Teachers' awareness of the possibilities of CT and programming could be expanded by providing them with further understanding of different computational tools and CT-related substance areas to pique their interest. It seems especially important to pay particular attention to in-service teachers especially with low programming motivation as well as to conduct further investigations among pre-service teachers to further understand the current situation in initial teacher training. It would also be interesting to examine potential changes in teachers' and students' motivation, for instance, due the continued presence of programming in the newest national core curriculum as well as examine how other types of motivation may relate to teachers' CT instruction.

Alongside motivational incentives in spreading CT awareness among teachers, it is important to ensure that teachers are equipped with pedagogically effective ways to integrate CT that are also meaningful for the disciplinary nature of their subject. While there has been discussion about whether all teachers should be expected to include programming in their teaching, CT, the expected learning outcome of programming, has been expressed as being cross-contextual (Wing, 2006), and there are many concrete examples of integrating these topics across the curriculum (see e.g., Settle and Perković, 2010; Moreno-León et al., 2017). Training should thus also consider solutions on how the manifold aspects of CT could be content-wise reflected in the lessons of different subjects. It appears crucial to spread awareness especially regarding such more cross-contextual CT activities as understanding diagrams and using real-world data to solve problems with computational methods (see e.g., Barr and Stephenson, 2011; Grover and Pea, 2013). Thus, also the extents and ways in which teachers of different subjects emphasize different aspects of CT (see **Figure 1** and **Table 1**) could also be studied more thoroughly in the future. Additionally, expanding pedagogical possibilities in the more non-problem-solving aspects of CT, that is, the dimension of computational multiliteracy (see Kafai et al., 2019; Høholt et al., 2021; Mertala, 2021) concretely for different school subjects could be highly impactful.

To support teachers' overall teaching success in CT instruction, it can be vital to also consider how comfortably teachers can adopt different kinds of CT-related pedagogical contents (Sentance et al., 2019; Rich et al., 2021) and what role teachers' CT self-efficacy can play in professional learning in CT (see also Mühling et al., 2010; Yukselturk and Altiok, 2017; Garvin et al., 2019). Future teacher training and research should thus also critically and meticulously consider teachers' subject and pedagogical content knowledge in CT (see Mäkitalo et al., 2019; Kong et al., 2020). Additionally, the availability of teaching materials and assessment practices (Weintrop et al., 2019) and even such mundane factors as time for lesson planning (Waite et al., 2020), time in the syllabus, and time altogether for professional development are important, turning focus also into school resources and school leaders' decision-making. Illustratively, in Finland, only 58% of school principals rated the educational outcome of developing students' skills to write apps or programs as quite important or very important (Strietholt et al., 2021, p. 28), showing that nearly a half of school principals do not perceive students' programming skills as important educational outcomes.

Teachers' broader adoption of CT would likely also improve students' exposure to CT while studying different school subjects. However, in terms of students' programming motivation specifically, it is altogether vital to provide learning experiences that are interesting and enjoyable and that promote a sense of value and usefulness. The latter could be targeted by clearly highlighting the significant role of CT and programming in daily life and the world of professional work. Regarding the first, prior studies have already illustrated that programming in a variety of ways can be intrinsically motivating. Specifically, learners' positive attitudes have been shown to increase after, to name a few, designing games and animations in the contexts of creative computing with Scratch (Ruf et al., 2014), maker-like activities (Tisza and Markopoulos, 2021), "unplugged" activities (Jiang and Wong, 2017), (Lambić et al., 2021), and text-based programming (Asad et al., 2016). Students' motivational dimensions could thus be increased by providing personally interesting and enjoyable ways of programming from the variety of existing ways to do programming rather than through singular isolated introductions. Especially girls are in desperate need of such opportunities to diminish the prevalent views of programming being not for their gender. On the previous note regarding teachers' pedagogical content knowledge in CT, it is important to note that students' interest toward programming can wane when faced with difficult and tedious tasks (Dohn, 2019). Proper pedagogical planning in terms of appropriate instructional guidance (Lye and Koh, 2014) and collaborative, student-centered, and craft-oriented learning (Taub et al., 2012; Dohn, 2019; Sharma et al., 2019) can thus be crucial specifically from the viewpoint of student motivation and achievement.

Limitations

This study is not without limitations. The first limitation is the cross-sectional study design. Despite the large and representative sample and accounting for the effects of meaningful covariates, the present study was correlational, which inhibits assertions on causality. For instance, we were only able to hypothesize whether motivation may lead to increased instructional emphasis and learning or vice versa. Another limitation is that the sampling design in the study prevented certain potentially valuable analyses, such as cross-examining the responses of teachers and students in the same schools or classrooms. In addition, even though we measured intrinsic and extrinsic motivation for both students and teachers, the measures were not identical since the student measures focused on motivation for learning programming whereas teachers' measures focused on motivation in teaching programming. Otherwise, the items were identical apart from that the extrinsic motivation questionnaire consisted of three items for teachers and two items for students.

The international questions in the large-scale international comparative study were developed and the data was collected following a common approach agreed by several partners. The student questionnaire especially was broad, and therefore only few additional questions on motivation could be added to investigate select theoretical dimensions. Moreover, the data was self-reported by the teachers and students, and this setting can involve factors related to, for instance, self-esteem and self-presentation styles that can influence responses. The data was also collected in 2018, and the results thus indicate the situation on the eve of the new curriculum rather than its impact.

Conclusion

This study connects to the broad discussion and numerous educational initiatives surrounding CT in basic education both in Finland and globally. Our focus was on teachers' and students' programming motivation and its role in the instruction emphasis of CT among teachers of different subjects and Grade 8 students' CT proficiency as demonstrated by their ICILS 2018 CT test results. As shown by previous research and the current study, the different ways of integrating CT across school subjects especially through the problem-solving aspect prevalent in CT have not comprehensively found inroads to the instruction of most teachers in basic education. Therefore, also students appear to vary in terms of their exposure to and learning outcomes in CT, posing growing needs for basic education to bridge these gaps.

Programming motivation appears to have a modest positive relationship with teachers' CT instruction emphasis and students' CT proficiency, which is why it is important to consider in teacher training and pedagogical planning. On average, programming motivation is comparably high especially among teachers with prior experience in teaching programming, STEAM teachers, as well as male teachers. In turn, it is comparably low among teachers without prior experience in teaching programming, teachers who teach national and foreign languages and other subjects, as well as female teachers. For students, programming motivation is on average comparably high among students who have programmed previously and boys whereas students who have not programmed previously and girls have comparably low programming motivation. It appears especially important to consider how to promote especially teachers' intrinsic programming motivation and girls' programming motivation generally, although other as or more important factors influencing teachers' CT instruction and students' CT learning may include teachers' skills (Mäkitalo et al., 2019; Kong et al., 2020), available resources (Weintrop et al., 2019) and time (Waite et al., 2020), the amount or quality of instruction and learning experiences and learning activities (Lye and Koh, 2014; Sun et al., 2022), and even students' personality traits (Román-González et al., 2017).

For spreading the word of CT in basic education more extensively, there is a growing need for teachers to understand CT more broadly than merely programming: CT should be regarded as cross-contextual computational problem-solving that can have benefits beyond mere code-writing contexts. It could also be presented for teachers more broadly as a type of multiliteracy, which involves teaching students to also examine the practical, political, and even ethical dimensions of the surrounding computational world critically (Høholt et al., 2021). This viewpoint emphasizes not just learning to employ computational tools and methods to solve logical problems but also understanding what computing means personally and socially, thus perhaps making more sense to teachers of different subjects (Mertala, 2021). Generally, in CT, there is also the need to continue adopting the more comprehensive viewpoints portraying it as one involving more data-driven machine learning notions as well, which are rendering the so-called "CT 1.0" (i.e., one involving the more traditional step-by-step computational methodologies) somewhat obsolete (Vartiainen et al., 2020).

Data availability statement

ICILS 2018 international database is available at the official IEA website (https://www.iea.nl/data-tools/repository). The national data analyzed in this study can be enquired from JF.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

JF made primary contributions to the manuscript working collaboratively with all authors. JF and KL were primarily responsible for the study design, and, with NK, for the literature review, data analysis, and interpretation. MN-R was primarily responsible for data organization and completing the statistical tests. All authors contributed to the manuscript and approved its submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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