

Comparison of STEM, non-STEM, and Mixed-Disciplines Pre-service Teachers' Early Conceptions about Computational Thinking

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ABSTRACT

This paper presents the results of an investigation on pre-service teachers' conceptions of computational thinking (CT) in Singapore prior to a two-hour introductory module on CT. Of 407 teachers, 280 provided valid responses to the pre-survey, which included questions on teachers' school subjects, current understandings of CT, confidence in their understandings of CT, and sources of the understandings. We deductively coded the open-ended responses through thematic analysis using four categories from a synthesis review on teachers' preconceptions of CT. The participants were classified into three groups, including STEM (primarily sciences and mathematics), non-STEM (e.g., humanities and languages), and mixed-disciplines (e.g., science and English language arts). The findings of the pre-survey showed that 42% of respondents (n=118) reported no prior knowledge of CT. Among the remaining 162 responses, the most popular view of CT was problem solving using various kinds of thinking, such as "logic", "abstraction", "step-by-step", and "decomposition" (n=106). STEM and mixed disciplines teachers (33%) reported higher levels of confidence compared to non-STEM teachers (15%). A higher percentage of STEM (64%) and mixed-disciplines (60%) pre-service teachers indicated learning about CT from formal courses during their university studies or teacher training, compared to non-STEM teachers (52%). This suggests that schools of education can play a bigger role in expanding CT awareness among pre-service teachers from non-STEM backgrounds. Finally, implications for teacher education are widely discussed.

KEYWORDS

computational thinking, teachers, conceptions, STEM, survey

1. INTRODUCTION

In 2020, Singapore updated its plan on developing digital literacy in general education to include computational thinking (CT) (Learn for Life, 2020). Existing programs that teach computational thinking (CT) through coding, robotics, and physical computing were scaled to more schools. The Ministry of Education (MOE) produced a guide on teaching CT in secondary level mathematics, reflecting a popular approach of integrating CT into existing subjects (Huang et al., 2021; Lee & Malyn-Smith, 2020; Pollock et al., 2019; Sherwood et al., 2021), rather than as a standalone subject, or only in computing classes. As applications of computing has led to fundamentally new advances in knowledge production across disciplines (e.g., Arnold, 2020; Qin, 2020), integrating CT could provide new perspectives on various subjects of study, as well as

prepare students with relevant work skills that could spur technological innovations across sectors.

To achieve these educational objectives, training and supporting teachers are essential activities. In 2017 and 2018, we developed a day-long module to introduce all graduating Singapore pre-service teachers to CT, through activities that included Scratch programming, unplugged games, and microprocessor programming. As the staffing requirement became unsustainable, we redesigned the module as a 3-hour interactive lecture that could be delivered by 2 instructors for cohorts of several hundreds.

To evaluate and guide the improvement of the module, a survey was administered prior to and immediately following each session. Since all pre-service teachers across subjects and levels were required to participate in the module, the survey responses could provide insights on early conceptions of CT held by different groups of teachers. The results of an earlier study showed differences in views of CT by STEM (science, technology, engineering, mathematics) teachers compared to non-STEM teachers (Looi et al., 2020). However, the study did not account for teachers who were trained in both a STEM and a non-STEM subject. Also, the open coding surfaced 65 labels, the majority of which had a frequency of 1 and were not included in the final analysis. For this new study, we included a third category of teachers ("mixed-disciplines") and accounted for all responses in the analysis. We investigated the following questions:

1. What are the differences in conceptions of CT between STEM, non-STEM, and mixed-disciplines pre-service teachers?
2. What are the relationships between confidence, source, and content of CT knowledge expressed by pre-service teachers?

2. BACKGROUND

As CT gained prominence as an educational objective for all students, more attention has been given to preparing educators to teach CT (e.g., Hestness et al., 2018; Yadav & Berthelsen, 2021). Barr and Stephenson (2011) proposed an expansive agenda to embed CT in the K-12 curriculum, calling upon the cooperation of multiple stakeholders. As a result, it is increasingly likely that teachers have *heard of* CT before *learning about* CT in a professional context. Also, teachers may have preconceptions based on the two words in the term itself. A better understanding of these early conceptions may help teacher educators and researchers anticipate and address them in professional learning or teacher preparation courses.

Cabrera (2019) synthesized recent literature on teachers' preconceptions of CT (e.g., Corradini et al., 2017; Garvin et al., 2019; Bower & Falkner, 2015; Yadav et al., 2014).



We adapted 4 relevant preconceptions, which were:

1. CT as technology integration
2. CT as equal to CS and programming
3. CT as a non-specific problem-solving strategy
4. CT as “thinking like a computer”

Of the 24 papers he reviewed, only one study contained all four preconceptions (Corradini et al., 2017). There were three other studies that had three of the four preconceptions (Bower et al., 2017; Garvin et al., 2019; Yadav et al, 2018). By adapting his categories to code our data, we could corroborate our findings with prior studies and demonstrate the usefulness of the categorization.

There was only one other study that we are aware of that compares the CT conceptions of STEM and non-STEM teachers (Sands et al., 2018). The researchers pre-identified ten conceptions and asked teachers how much they agreed that each counted as CT. They concluded that there was no difference between the two groups. In our study, we did not set out to determine how well teachers could identify correct and incorrect conceptions of CT. We asked the study participants to tell us their understanding of CT without imposing any constraints.

3. METHOD

3.1. Respondents

The National Institute of Education (NIE) is the sole teacher training institute in Singapore. In November 2021, of the 407 graduating pre-service teachers who attended the required Introduction to CT session, 280 provided valid responses to the pre-survey. Most of the teachers who participated in the study were trained to teach non-STEM subjects (n=164, 59%), which included English Language, Literature, General Paper, History, Social Studies, Geography, Economics, Mother Tongue (Mandarin, Tamil, Malay), Character and Citizenship Education, Art, Music, Drama, and Accounting. Teachers categorized as STEM teachers taught Science, Mathematics, and Computer Applications (n=45, 16%). The mixed-disciplines teachers were trained to teach an English subject and a Science or Mathematics subject (n=71, 25%) (see Figure 1).

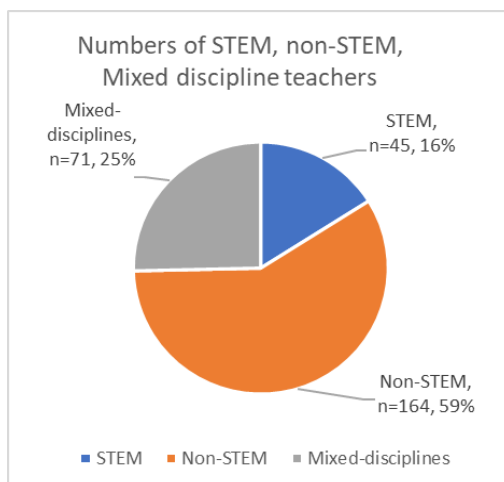


Figure 1. Numbers of teachers in each category

3.2. Survey

The survey consisted of four questions as shown in Table 1.

Table 1. Survey Questions.

Question	Response Mode
1. What subject areas have you been prepared to teach?	Check boxes
2. Rate your level of knowledge about “computational thinking”	Select radio button from 1 (“none”) to 5 (“confident I can explain it”)
3. What is your current understanding of “computational thinking”?	Open-ended text box
4. Where did you hear about “computational thinking”?	Open-ended text box

The respondents answered the questions using a google form. The data was cleaned and analyzed using spreadsheet software. Incomplete and vague responses were removed (e.g., “a little”, “3”). For question four, 21 responses were considered invalid because the respondents reported no knowledge of CT but listed a source for hearing about CT.

Each response was assigned to one of three categories of teachers (STEM, non-STEM, mixed-disciplines). Each column could be filtered and sorted to explore potential relationships among the data.

We developed our codebook (Table 2) using the four categories of preconceptions (Cabrera, 2019).

Table 2. Codebook of CT Conceptions.

Code	Definition	Examples
Technology integration	Working with technological tools or studying technology. Using computer devices or software.	- “Application of computer software and data to work” - “Uses a computer to solve problems”
Computer Science or programming	Programming as the operationalization of CT. The thinking process of programmers. Thinking like a computer scientist. Applying CS techniques or principles when solving problems.	- “Knowledge about computer science?” - “Solving problems like a computer scientist, in a way that computers could also execute”
Problem solving or general thinking	Problem solving that involves higher order thinking skills such as abstraction, logical thinking, critical thinking, decomposition, among others. CT as a kind of problem-solving strategy that	- “How to solve problems systematically” - “Breaking problems down into simpler problems parsed in step-by-step terms a computer could

	enables people to create solutions for computational agents to carry out.	solve. Requires abstraction, i.e., the elimination of irrelevant details.”
“Thinking like a computer”	Adopting the same process that a computer uses to “think”.	- “Thinking logically like a computer to complete problem-solving tasks”
	Understanding how a computer processes information so that humans can design instructions for computers to follow.	- “Breakdown of the thinking process that can be emulated by computers”
Other	Anything that doesn’t fall in the above categories.	“Understanding how to use or apply formulas and (mental) operations in order to solve problems”

A sample (n=50) was independently coded by the three authors. Each response could be coded in more than category. 22 of the 50 responses had “none” for understanding of CT so were easily agreed upon. After resolving most of the differences among the remaining 28, the first author coded the remaining 230 responses.

The open-ended responses for question four were coded using constant comparison over several iterations, beginning with labels such as, “online”, “TED ed”, “Youtube”, “reddit”, which were then combined to form the category “internet / media”. This process resulted in five categories, of which the other four consisted of “university”, “NIE”, “friends/family”, and “guess”.

4. FINDINGS

Of the 280 respondents, almost half (n=118, 42%) reported no prior knowledge of CT. Of these 118 “none” responses, non-STEM teachers made up a disproportionate amount (n=83, 70%), despite only representing 59% (n=164) of the total participants. Mixed-disciplines teachers were underrepresented, constituting 25% of the total participants (n=71) but only 20% (n=23) of the “none” respondents. STEM teachers were also underrepresented, constituting 16% of the total participants (n=45) while making up 10% of the “none” respondents (n=12). The results are shown Figure 2.

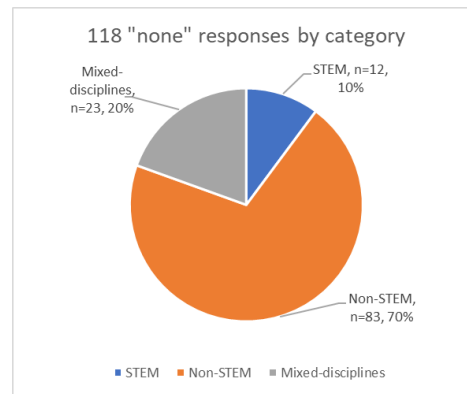


Figure 2. Distribution of teachers by category who reported having no knowledge of CT

Among those who reported having some conception of CT, there were gaps in confidence of their knowledge among the three groups of teachers (Figure 3 of the appendix). The results showed that overall, STEM teachers reported higher levels of confidence relative to mixed-disciplines and non-STEM teachers. 39% of STEM teachers (n=13) reported confidence levels of 4 and 5, compared to 27% of mixed-discipline teachers (n=13) and 15% of non-STEM teachers (n=12). In fact, zero non-STEM teachers reported a 5 in confidence. Additionally, 44% of non-STEM teachers (n=36) reported having the lowest possible level of confidence (level 2) in their conception of CT.

The results for CT conceptions are summarized in Figure 4, found in the appendix. The most popular conception was “problem-solving/thinking” (64% of coded responses) but there was variation among the three groups. For STEM teachers, this conception made up 67% of responses; for mixed-discipline, 73%; and non-STEM, 57%. Responses categorized in “technology integration” made up the smallest percentages (STEM: 3%; mixed-disciplines: 4%; non-STEM: 6%). Overall, the responses of non-STEM teachers were more varied across the four categories.

The results for sources of knowledge about CT are reported in Figure 5 of the appendix. The most popular source of knowledge about CT came from the teachers’ university studies prior to the teacher training programme (37% of 148 valid responses). The STEM and mixed-disciplines teachers who named “university” had similar percentages (42% and 44%, respectively) compared to 31% of non-STEM teachers. These numbers may reflect recent university policies requiring undergraduate students to undertake coursework that includes CT. But there appears to be a gap between university students who pursued STEM versus non-STEM majors with respect to learning about CT. When combined with the percentages of responses that named NIE and other courses, 64% of STEM teachers learned about CT from a “formal” educational context compared to 60% of mixed-discipline teachers and 52% of non-STEM teachers. Also, 29% of non-STEM teachers heard about CT through an internet search or popular media, compared with 19% of mixed-disciplines teachers and 17% of STEM teachers. These statistics suggest a need for more non-STEM teachers to learn CT in a substantive context instead of through an internet search or popular media.

We observed an interesting relationship between confidence level and sources of CT knowledge. Teachers with the lowest confidence reported getting their knowledge of CT from friends/family by a factor of two relative to the responses of all teachers. However, the teachers who reported confidence levels of 4 and 5 relied one-third less on media/internet and 1.5 times more on their university studies relative to the responses of all teachers. Teachers who named NIE as their source of knowledge were half of those who reported “university” and less than those who learned about CT from the media/internet.

5. DISCUSSION

5.1. Addition of a “mixed-disciplines” category

Having a separate “mixed-disciplines” category did not seem to contribute much to this analysis. If we had combined the STEM and mixed-disciplines groups as a category of teachers trained to teach at least one STEM subject, the combined numbers would still constitute only two-thirds of the cohort but provide a better comparison with non-STEM teachers. For instance, the combined group would still be underrepresented among those reporting no knowledge of CT (i.e., 30% of “none” responses, but 41% of overall respondents).

5.2. Conceptions of CT

The four categories of CT conceptions fit our data well. Only 11 of the 280 responses were coded in the “other” category. Our findings showed that CT as “problem solving” was dominant (n=106), followed by much smaller numbers, “CS/programming” (n=23), “thinking like a computer” (n=20), and “technology integration” (n=8). As a cohort representing different subject areas and grade levels, our teachers’ views were consistent with those reported by other researchers. Table 3 shows the top three or four preconceptions identified by a sample of similar studies, prior to professional development.

Table 3. Comparison with similar studies

Authors	Context	Top CT Preconceptions
(Yadav et al., 2014)	Pre-service teachers (control group, n=153)	Control group responses: “problem solving, logic”, “use of technology, computers”, “algorithms, step-by-step, directions”
(Yadav et al., 2017)	Pre-service teachers (n=134)	“problem solving”, “logical thinking”, “other types of thinking”
(Bower & Falkner, 2015)	In-service primary school teachers (n=32)	“problem solving with or using technology”, “various types of thinking” (e.g., logical, analytical, mathematical)
(Bower et al., 2017)	In-service teachers (n=69)	“problem solving”, “logical thinking”, “coding”, “using technology”
(Corradini et al., 2017)	In-service teachers (n=779)	“problem solving”, “mental processes”, “logical thinking”, “algorithmic thinking”

Across groups, problem solving was the most common. We noticed that respondents often related mental processes, such as logical thinking, decomposition, algorithmic thinking, abstraction, and other forms of thinking to problem solving. However, our study had few teachers who thought of CT as “using technology or computers” compared to the teachers in other studies (e.g., Bower & Falkner, 2015; Bower et al., 2017; Yadav et al., 2014).

In our analysis, we could not conclusively claim that there were any significant differences between the conceptions of STEM, mixed-discipline, and non-STEM pre-service teachers. If we combined the teachers who were prepared to teach at least one STEM subject, 70% of them considered CT as problem solving compared to 59% of non-STEM teachers. The conceptions by non-STEM teachers were more varied across the four conceptions. There was a gap in the confidence levels between STEM and non-STEM teachers, which may be attributed to STEM teachers having more exposure to CT in formal education while non-STEM teachers relied more on information from the internet or friends.

We concur with Cabrera (2019) that what matters is not whether teachers have correct or incorrect ideas, but that their preconceptions are starting points for developing better understandings. The survey results on teachers’ early conceptions can inform efforts to integrate CT into the pre-service teachers’ curriculum studies. For instance, since problem solving was the most popular CT concept, we could help teachers identify which problems are suitable for applying CT in different subject areas. We could help teachers better understand the difference between how humans think and how computers process information. We could show how some uses of technology promotes CT. We could help teachers maintain a link between CT and computer science or programming without equating them.

6. LIMITATIONS

By giving respondents the option to say that they had no prior knowledge of CT, we likely missed out on other preconceptions that could have resulted in a different distribution among the four categories. The open-ended responses were sometimes difficult to interpret without more details from the teachers, such as interviews with a sample of the respondents from different categories. Our survey design lacked rigorous psychometric properties needed to uncover statistically significant differences between the groups of teachers. Hence, the findings’ primary purpose is descriptive.

7. CONCLUSION

Our investigation corroborated existing studies of teachers’ conceptions of CT prior to professional learning and contributed insights on relationships between preconceptions, knowledge source, and confidence levels. Many pre-service teachers were still not familiar with the term. Among those with some exposure, the greatest association of CT was with problem solving and various forms of thinking, followed by CS/programming, “thinking like a computer”, and technology integration. Non-STEM teachers disproportionately made up more of the group who reported no knowledge of CT. A greater percentage of non-

STEM teachers also reported lower confidence levels than teachers who were prepared to teach at least one STEM subject. We attribute the gap to unequal access to formal learning about CT prior to or outside the teacher training programme. We argue that schools of education can therefore play a greater role in providing teachers with opportunities to learn CT as part of their curriculum studies. Rather than seeking to replace teachers' "misconceptions" about CT, teacher educators can design content that support teachers developing more nuanced and specific understandings.

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9. APPENDIX

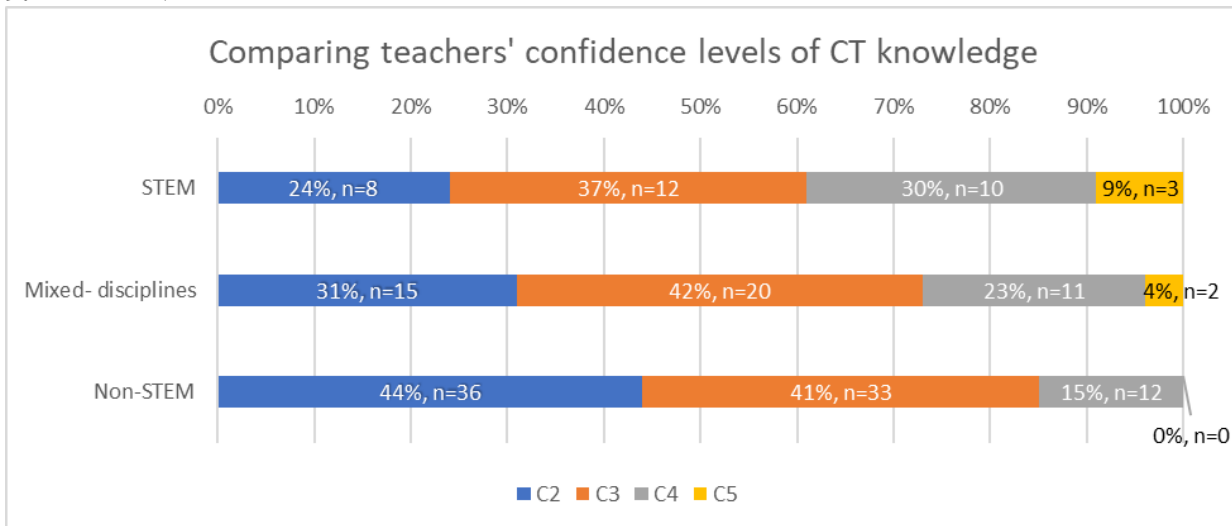


Figure 3. Comparing teachers' confidence levels

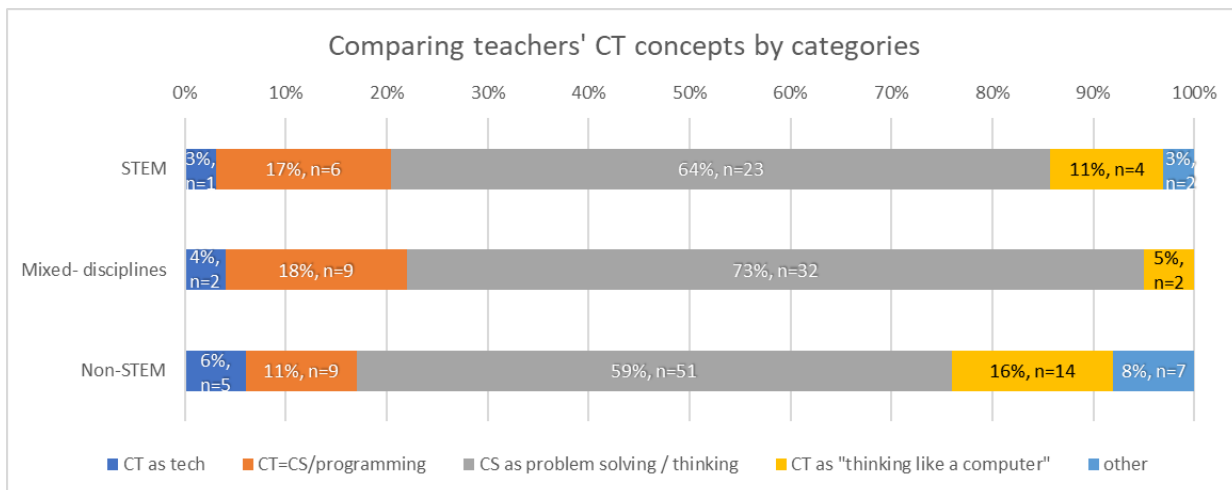


Figure 4. Comparing teachers' CT conceptions

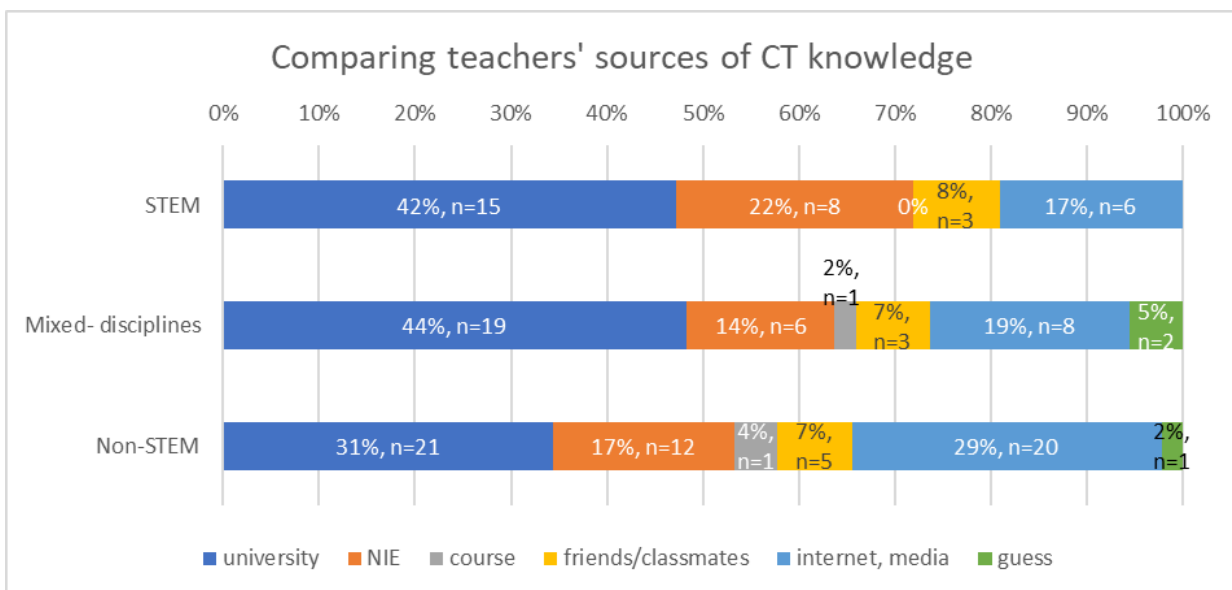


Figure 5. Comparing teachers' sources of CT conceptions