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Understanding and Developing In-Service Teachers' Perceptions towards Teaching in Computational Thinking: Two Studies

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Abstract: In Singapore, O-Level Computing for grade 9 and 10 students was first offered as part of formal education in 2017. Due to a lack of computing teachers, the initial batches of O-Level Computing teachers were professionally developed from those who were already teaching other subjects such as math and science via a conversion course conducted by the Ministry of Education, Singapore. Beyond merely teaching about computer programming, the teachers would need to be trained to teach Computational Thinking (CT), as CT has many practical applications in real-world problem-solving. Therefore, it is imperative to understanding more about in-service teachers' perceptions about CT when they were converted into computing teachers from other subjects. In the current paper, we proffer unplugged approach that could be deployed for teachers to develop notions and confidence about Computational Thinking, which could have implications for teacher professional development at a larger scale.

Keywords: Computational Thinking, Unplugged, Teacher Professional Development

1. Introduction

Computational Thinking is defined by Wing (2006) as "solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science". Proponents of CT in the UK, US, Korea, Hong Kong, New Zealand and Germany took the initiative of integrating it into their formal school curricula. In the extant literature, research interest in CT has led to studies regarding computing teachers' perspectives, motivation, levels of competency and confidence in curriculum change, suggesting that there is high demand for teachers' professional development (PD) in computing education. Bower, Lister, Mason, Highfield and Wood's (2015) study about the pre-service teachers in Australia shows that many teachers have misconceptions about CT structures and this might be detrimental to developing students' CT capabilities. By surveying 91 New Zealand digital technology teachers, Thompson, Bell, Andreae and Robins (2013) recognized that lack of confidence in teachers is a main issue and PD opportunities such as the CS4HS workshop and support from university-based experts might help to boost confidence and self-efficacy of teachers. Some CT training workshops for teachers focus on K-12 students, such as the one offered by Franklin et al. (2015) which provides advice for best practices in curriculum, content delivery, interfacing with schools, and classroom layout.

One of the educational approaches to developing CT is "Computer Science (CS) Unplugged" which introduces CS concepts to non-specialists through hands-on activities without the use of a computer (Bell, Witten & Fellows, 2005). Some studies have shown that this approach has been used successfully with students of a wide range of ages in different countries due to the fact that it allows students to learn and understand CS concepts in an entertaining way and with high motivation (Nishida, Kanemune & Idosaka, 2009). While the majority of the research recognizes the effectiveness of unplugged approach in enthusing students in computing, there are also studies showing the difficulties that teachers faced in teaching unplugged. Two main difficulties that identified by Choi, Bell, Jun, and Lee (2008) are the gap between unplugged activities and how it relates to CS, as well as the way to evaluate the unplugged teaching. After analysing 115 responses from British ICT teachers, Black, Brodie, Curzon, Myketiak, Mcowan and Meagher (2013) also assert that teachers mainly mentioned using unplugged approach to enthuse students but not to teach deep computing principles.

This paper seek to gain a better understanding of in-service computing teachers' needs and build up teachers' competencies in using unplugged approach for teacher professional development. It consists two studies. Study 1 is a teacher survey to seek their attitudes, understanding and challenges in teaching computational thinking. Study 2 is a teacher workshop using unplugged approach to demonstrate how professional development that involving guided instruction and hands-on practice can help to build up teachers' confidence and capability in teaching CT.

2. Background

In 2014, Singapore launched the Smart Nation Programme which is National wide effort in harness technology in sectors of business, government and home to improve urban living, build stronger communities, grow the economy and create opportunities for all residents to address the ever changing global challenges (Smart Nation, 2017). To support the Smart Nation initiative, one of the key enablers is to develop computational capabilities. Programmes are implemented to introduce and develop CT skills and coding capabilities from pre-school children to adults. We have surveyed the landscape of K-10 CT and coding related programmes in Singapore which are implemented by various government organizations. Unlike countries like Finland, England and Korea, Singapore is not including Computing or CT as compulsory education. Instead, Singapore' approach is to provide opportunities for students to develop their interests in coding and computing skills through touchpoint activities at various ages.

In the beginning of 2017, Singapore's Ministry of Education (MOE) implemented a new GCE O Level computing curriculum for upper secondary students (ages 15 to 16). The new curriculum is a distinct shift from teaching students on the use of software technology to the development of Computational Thinking (CT) skills and programming competencies. While addressing the shift of focus in computing education at the national level, the following are two challenges that need to be addressed: teachers' content knowledge and pedagogical competency on teaching computational thinking. Thus, we embarked on a two-year long project that has a focus on building teachers capacity in teaching computing, starting with the unplugged approach as introductory pedagogy for teaching computing.

3. Methods

3.1 Study 1: A Teacher Survey

To better develop and evaluate pedagogy that can support computing teachers in their educational mission, we first seek to understand teacher's perceptions on computational thinking, attitudes and readiness towards teaching CT, and the challenges they are facing. This is done by conducting a teacher survey using the Qualtrics online survey tool. The survey comprised 17 questions and was designed mainly to gain insight into these 3 aspects: 1) The background of the teachers; 2) The understanding, the interest level, the ability and challenges in teaching, and the willingness to learn regarding computational thinking; 3) The familiarity, the interest level, the ability to teach and the willingness to learn regarding the unplugged approach, being one of the ways to teach CT.

Quantitative data was analyzed and reported using standard statistics techniques. Open-ended questions were interpreted by techniques such as identifying and classifying recurrent themes.

The target audience for the survey is the teachers who are going to teaching the new computing subject. The survey was digitally delivered to the teachers during the pedagogy workshop held by Curriculum Planning and Development Division (CPDD) of Ministry of Education, and in total 36 teachers (27 male and 9 female) from 19 schools in attendance participated in the survey.

3.2 Study 2: A Teacher Workshop

A teacher workshop using unplugged approach was designed and conducted in order to address the problems that were identified from the teacher survey. The effectiveness of this workshop was assessed by a pre-survey and a post-survey. Considering its simplicity in teams of procedure but also profoundness in term of content, we selected unplugged activity as an elementary pedagogy at the early stage of our study. We hope that through this workshop:

1. Awareness and interest in unplugged activities would be triggered among teachers and they would start considering the relevance and usefulness of unplugged activities to the subjects they are teaching, be it the new computing subject or any other subject.
2. Teachers are able to enact some computing unplugged activities into their classrooms, and think about the teaching flow leading to writing pseudo-code/code in the case of teaching computing.
3. We as the researcher could have some insight into the possibility of large scale implementation for teachers' professional development, and hence start to plan our future work based on the results and findings from the workshop.

Figure 1. Teachers from two secondary schools participating in the unplugged activities of the workshop

Our target audience for the workshop was 9 teachers from two secondary schools which are the partner schools for the project (Figure 1).

The 3-hours workshop was structured around 6 unplugged activities: sorting algorithms, sorting network, binary numbers, variables, deadlock avoidance and searching algorithm. These are the topics considered most relevant to secondary students according to these 9 teachers that we talked to before designing the workshop. In terms of content, we followed the online resource CS unplugged (http://csunplugged.org/) and Barefoot Computing (http://barefootcas.org.uk/). Each activity includes five parts: introduction, trial, discussion and sharing, video demonstration and reflection. The main idea behind the design of the lesson flow is to motivate participants with real-world problem in the introduction part; bring out some relevant questions, provide them the activity props and let them figure out the solution by themselves in the trial; let participants discuss and share with each other their own solution in the third part; last but not least, watch the demonstration video and reflect on the way to incorporate it in their teaching.

Pre-survey and post-survey with more or less the same set of questions were conducted in order to assess the effectiveness of the workshop and collect teachers' feedback towards this workshop. These two questionnaires are comparatively short, with two demographic questions relating to name and years that have been teaching, three questions that examine respondents' interest, perception and confidence in teaching unplugged, and two open-ended questions oriented towards the respondents' understanding of unplugged approach and its usefulness.

4. Results

4.1 Background of Computing Teachers

Among these 36 computing teachers ((27 male and 9 female) in the survey, 25 of them (69%) responded that they have computing-related background such as a degree or diploma in computing-related major while the rest of them do not have. 28 out of 36 teachers (78%) have taught computing or computing-related subject in school while the rest of them have no experience in teaching computing. Among these 28 experienced teachers, 24 of them (86%) have taught the computing-related subject for more than 3 years while 3 teachers (11%) have 1-3 years' computing teaching experience and 1 teacher (3%) has less than 1-year experience. It is important to note that a high percentage --86% of the teachers in our survey sample are very experienced in teaching computing, and also to note that regardless whether they have a computing-related background, all these 36 teachers actually went through the one-year long computing conversion class provided by MOE before they took this survey. The information about teachers' background would be used as a benchmark in the following part of the analysis, i.e. to see how teachers' understanding of CT and teaching competency match up to their level of experience in teaching computing.

4.2 Computing Teachers' Understanding of Computational Thinking

29 out of 36 teachers (81%) responded that they have known about computational thinking before and the answer to the opened question "what is your current understanding of computational thinking?" from these 29 teachers are coded manually into categories of identified key words.

Table 1. Summary of teachers' understanding of "Computational Thinking".

Key Words	Count
solve problem/problems	25
thinking/thinking process	12
computer/machine	9
logical	8
algorithm/algorithmic	7
systematical way	6
decompose/break down problem	6
human/human behavior	5
formulate/define problem	4
computer science	3

From Table 1 we can see that among the 29 responses, the most frequently used phrase is "solve problem/problems". One answer even specifies that CT is to solve real life problems. Note that the second most frequently used phrase is "thinking/thinking process", which means that what underlines "solve problem" is actually "the thinking process" instead of "the results or outcome" as it is usually supposed to be. In terms of tools, 9 responses relate CT to the use of computer/machine, while 6 responses identify that CT can be also related to human/human behavior, which is without the use of computer/machine. There is no clear incorrect understanding of CT in these 29 responses, but different level of sophistication in teachers' understanding was observed. The majority of the responses associate CT with the terms like "logical", "algorithmic", "systematic", "decompose" which elaborate the inner characteristic of CT. Only 3 responses did not include any elaboration but only stated the main identity of CT as "problem solving".

To further look into teachers' understanding and awareness about the curriculum change, which shifted its focus from ICT as computer literacy to CT in computer science (CS), we asked teachers to classify CS activities against non-CS activities. Questions and results are shown in Figure 2. "Programming and Coding" and "Creating new software" are considered part of computer science. "Creating Documents or Presentations on the Computer" and "Searching the Internet" are generally not considered part of computer science but part of Computer Literacy. From statistics of the results we notice that all teachers understand correctly that "programming and coding" is CS activity, while 11% teachers mistook "creating new software" as non-CS activity and 25% teachers wrongly consider the last two activities as part of CS. Combining the analysis from the above two questions which target at knowing teachers' understanding about CT, it is clear that teachers have a generally good understanding of CT while some teachers have misconceptions about the focus of CT or CS.

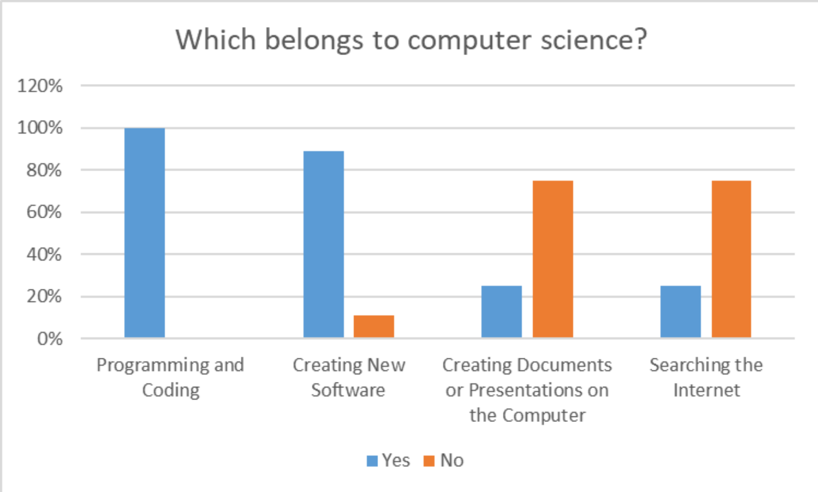

Figure 2. Teachers 'Understanding of CS Skills

4.3 Computing Teachers' Attitudes Towards Teaching CT

As shown in Figure 3, respondents were asked to rate on the following scale: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. From the table it can be seen that all the teachers either agree or strongly agree that incorporating CT into their class is important. However, considering the confidence in teaching and their conception about the complexity in teaching CT, we notice that 14% of teachers did not know how to teacher CT while 14% remained neutral; 20.5% of teachers agreed or strongly agree that CT is too complex to use while 28% remained neutral; 10% of teachers did not consider themselves as confident in teaching CT while 35% remained neutral. Therefore, a discrepancy between the desire to incorporate CT into the teaching and the confidence and ability to incorporate it was observed among the teachers.

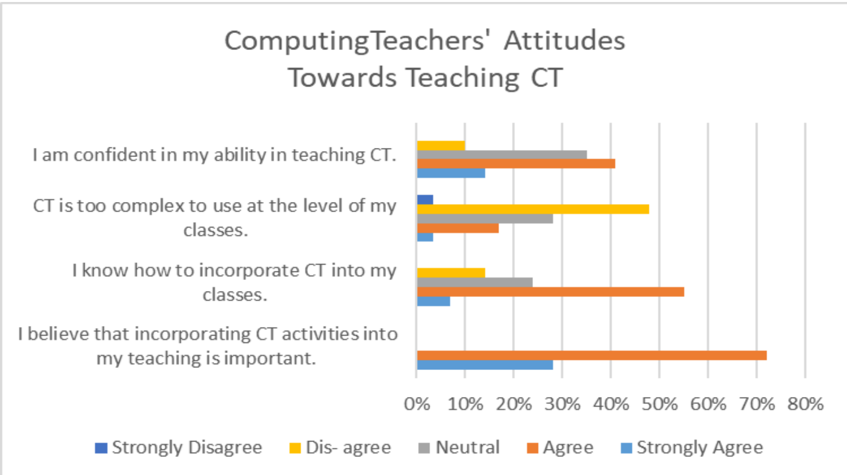

Figure 3. Teachers Attitudes towards Teaching CT

All 36 teachers were asked to rank the following 7 learning outcomes in the order from which they think is most important (1st ranking) to least important (7rd ranking): examination results, creativity, interest and passion, problem solving skills, reasoning skills, programming and coding skills, experience with technologies. The three most important learning outcomes from teachers' point of view are firstly "interest and passion", secondly "problem solving skills" and thirdly "reasoning skills". And the two least important learning outcomes which have the same number of counts in the last ranking are "examination results" and "experience with technologies (software or apps)".

4.4 Computing Teachers' Challenges Towards Teaching CT

A multiple-choice question on “what are the challenges you face (or expect to face) in teaching computing?” was asked in order to identify the most challenging factors that teachers face in teaching computing (Figure 4).

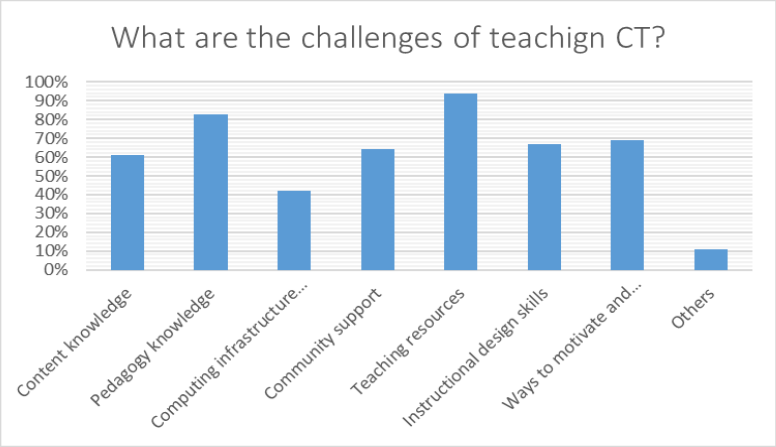

Figure 4. Teachers Challenges towards Teaching CT

Among the 9 provided choices of challenges, teaching resource (94%) ranks the first and pedagogy knowledge (83%) ranks the second, prominently. Even in the open-ended question for “Others”, teachers also mention that they need shared lesson plans and best practices by other schools. It is obvious that teachers are much more concerned about the resource for teaching and how to teach rather than what to teach, i.e. content knowledge.

4.5 Computing Teachers’ Changes Before and After the Workshop

As stated before, a teacher workshop using unplugged approach was designed and conducted in order to address the problems that were identified from the teacher survey. The effectiveness of this workshop was evaluated by a pre-survey and a post-survey with almost the same set of questions. 9 teachers from two different secondary schools participating in this workshop completed both surveys. They were asked to rate how strongly they believe a statement on a 7 point Likert scale where 1 represents strongly disagree (not at all interested, not at all useful and not at all confident) and 7 represents strongly agree (very interested, very useful and very confident). Figure 5 and 6 show the comparison between the pre-survey and post-survey results on the questions.

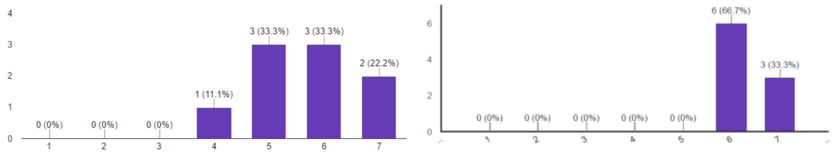

Figure 5. Development of Perceived Value of CT

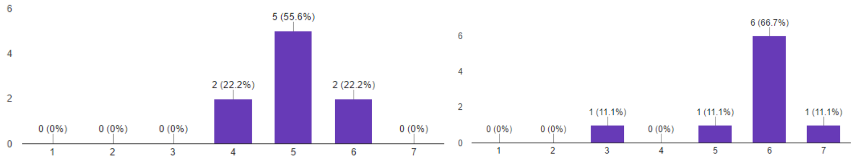

Figure 6. Development of Change of Confidence

Generally speaking, improvements in participants’ interest level of unplugged approach (Q1: 6.11/6.44), perception of unplugged approach’s usefulness (F = 2.309, $p < .05$), and confidence in teaching CT (F = 2.308, $p < .05$). As to the open-ended question that asked about teachers’ current understanding of unplugged approach, the identified key words shift from “use of non-ICT tools” to “fun activities to build concepts” (Figure 7).

Figure 7. Teachers' transformed understanding of Unplugged Approach

We also interviewed with two teachers participating the workshop. They complained that "we do not have the one-year training in teacher training institute on computing like other subject teachers". Thus, the workload for computing teachers is high since they have to learn and teach at the same time all by themselves. Both teacher 1 and teacher 2 are math and science teacher before they started to teach computing. Teacher 1 had a bachelor degree minor in computing where he received aggressive training due to a particular professor's teaching style. During our meetings, he often referred back to how he learnt programming in university when talking about how to teach certain content to students. Thus his ideology of teaching computing is also a bit aggressive, which means that he believes the good students do not need to be taught and should learn on their own by doing and exploring. He said, "Most of my attention goes to the low-achieving students while I am hands-off for the high-achieving students as they can already explore by themselves." Teacher 2 is more conservative compared to teacher 1. He teaches more slowly and caters for every student' need. He said he always want to try out the unplugged way of teaching computing. But before the researchers demonstrated the unplugged pedagogy to him by conducting a workshop, he did not have the initiative to try out on his own due to the worry of lacking time and materials. Therefore teacher 2 teaches in the traditional way most of the time.

5. Discussions

Summarizing the findings from the survey study, 86% of the teachers have more than 3 years' teaching experience in computing-related subject. All of them have undergone the one-year long computing course provided by MOE to prepare them to teach the coming new computing subject. Not surprisingly, these teachers generally have good understanding of CT and the importance of incorporating it into classes. Their expectation of students' learning outcome focuses more on students' interest, problem solving skills and reasoning skills instead of examination results and the use of technology. However, these teachers were not ready to teach the new computing subject. Quite a portion of teachers lack confidence in teaching and the main factors that contribute to their lacking of confidence are teaching resource and pedagogy knowledge.

This workshop had achieved its goal in triggering interest in teaching unplugged and building teachers' confidence as well as capability in teaching CT. From the workshop feedback, we also noticed that teachers really welcomed guided instruction and hands-on practice in unplugged activities. This is a good demonstration of how to use a comparatively low cost way of teacher development to encourage and equip teachers to teach CT in an interest-driven way. It is echoing to the theories of Biggs (1987) and Marton (1983) that learners develop interest in their task, they gain a deeper understanding of the subject, as they are motivated to understand the material, in an attempt to link new ideas to previous knowledge, and theories to everyday occurrences.

Nonetheless, it is noted that one participant felt less confident in teaching CT after attending the workshop. This would probably because some teachers are worried that the unplugged activities are too time-consuming as it is stated in the last open-ended question that asked what they like and dislike about the unplugged activities. We interpreted this in two ways: one is that teachers might not have enough time to prepare the materials and lesson plans for the unplugged activities, especially in the case that they are dealing with a completely new curriculum which they need to spend quite a lot time into digesting; the second is that adopting unplugged activities in class would take up too much class time which are already fully packed according to MOE's GCE O-Level Scheme of Work. To address teachers' concern about time-consuming, specific materials for unplugged activities and a systematic plan of unplugged lessons in line with MOE's computing curriculum should be provided and shared among the teachers.

6. Conclusion

Results from the teacher survey about CT suggest that generally teachers have good understanding about CT and have high motivation in teaching CT, but they are not confident in teaching CT as they do not have enough teaching resources and pedagogy knowledge. The following teacher workshop using unplugged approach is a good demonstration about how professional development that involves guided instruction and hands-on practice can help to build up teachers' confidence and capability in teaching CT. Despite its important implication for large-scale implementation for teachers' professional development, the problems identified in the workshop also needed to be addressed in the future work of this project. As to the future work, we will work with teachers to co-design a systematic plan of CT lessons that are in line with the MOE's computing curriculum as well as prepare the teaching materials that can be shared among the teachers. We will look into how different CT activities can be arranged and organized in the way that together they tell a better story of certain CT concept.

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