Designing Problem-Based Learning to Develop Computational Thinking in the Context of K-12 Maker Education

Megumi Iwata[1[0000-0001-7944-5157]], Jari Laru[1[0000-0003-0347-0182]], Kati Mäkitalo[1[0000-0003-4037-2872]]

[1] Faculty of Education, University of Oulu, 90014 Oulu, Finland
megumi.iwata@oulu.fi, jari.laru@oulu.fi, kati.makitalo@oulu.fi

Abstract. Computational thinking (CT) is a fundamental concept in the disciplines associated with information technology including informatics. Developing CT helps understand the principles of informatics. CT can be effectively developed through the facilitated problem-solving tasks in problem-based learning (PBL). This study introduces on-going project which aims to develop educational practices in PBL to foster CT. As a context to foster CT, the study chooses maker activities. Maker activities provide hands-on problem-solving experience which can enhance development of CT. Focusing on key aspects of PBL and teacher's facilitation of problem-solving processes, the study explores how CT can be effectively developed through maker activities. The participants of the study are in-service teachers and their pupils. The teachers design maker activities consisting of four sessions. Pupils' CT proficiency is assessed after each session and teachers improve the following sessions based on the assessment results. The study advances understanding of CT from learning science perspectives. The findings can be applied into pre-service and in-service teacher education.

Keywords: Computational Thinking, K-12 Education, Maker Education.

1 Introduction

Computational thinking (CT) shares its elements with principles and concepts of informatics. CT can be defined as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" [Cuny, Snyder, & Wing, 2010, as cited in [16]]. CT has been considered as a skill set which every child should have [15], and many countries (e.g., Finland, the United Kingdom, Japan) have initiated the curriculum reform to introduce the concept of CT at schools. Thus, currently, there are needs to develop approaches to integrate CT in the existing school practices and support teachers' professional development [10].

Jeng and colleagues [9] select the ten relevant components of CT and explain the connection between CT and the problem-solving cycle. *Problem-based learning* (PBL) provides opportunity to develop CT through suitably designed problem-solving tasks with teacher's facilitation [6]. In PBL, pupils commonly work in a small group and solve a complex problem which does not have single correct answer [3]. Ill-structured problem-solving and collaborative problems-solving are considered as the key aspects of PBL [6]. Teacher's role of facilitating problem-solving processes is crucial in successful PBL [11]. *Maker education* is a common context for PBL in K-12 schools. Maker education is built upon *constructionism* introduced by Harel and Papert [5], which highlights learning through making tangible artefacts [2]. Tangible making helps pupils grasp the abstract CT concepts, and ill-structured problem-solving processes with physical materials provide pupils with concrete experience to apply CT [8].

This study aims to develop educational practices in PBL to foster CT in the context of K-12 maker education. Focusing on the educational practices in PBL, this study explores how the key aspects influence development of CT and how teachers improve their role in PBL to foster pupils' proficiency of CT. The study is divided into the following three sub-studies:

1. To what extent is CT developed through PBL in the context of maker education?
2. In what ways is development of CT enhanced by the key aspects of PBL in the context of maker education?
3. In what ways do teachers improve facilitation of PBL in the context of maker education?

2 Related studies

The previous studies have proposed CT frameworks and models, however, there has not been a single definitive view of what CT includes. Some frameworks (e.g., [7,18]) include both cognitive (knowledge and practices of computing) and metacognitive aspects of CT (perspectives and attitudes of computing), while others (e.g., [12,13]) focus only on cognitive aspects of CT. Tang and colleagues [14] listed the assessment methods commonly used in the current literature, such as traditional test, portfolio and survey. They suggest using qualitative measures, such as interviews and think-aloud as supplemental assessments to deeper investigate CT proficiency.

In constructionism-based maker activities, informal formative feedback, which assist the progress of the project and provide opportunity to revise understanding, is part of culture [4]. Yin et al. [17] focus on assessing four aspects of CT concepts / capabilities: abstraction, decomposition, algorithm design, and parallel generalization, as well as CT disposition listed in [7]. They developed and test the assessment methods (open-ended CT integrated achievement test and self-report survey) based on the framework of learning outcomes of CT embedded in maker activities.

3 Methods

Participants of the study are in-service teachers and their pupils in K-12 schools in Finland. The teachers are chosen from the members of a regional network which promotes maker education by providing in-service teachers with training to design and implement maker activities. Background of the teachers in the network differs, from those who have skills in using ICT tools in teaching and learning to those who are not necessarily technology-oriented teacher. However, the training sessions include both technical contents and pedagogical contents regarding maker activities and CT, which enable the teachers to design, implement and evaluate suitable maker activities.

This study is design-based research (DBR) where in-service teachers plan and implement PBL activities in the context of maker education. Becker and Jacobsen [1] conducted DBR to study the development of teacher knowledge, pedagogy and practice through the maker activity sessions. In this study, an activity consists of four of a 90 minutes session, where pupils make an artefact in a small group. In the pre phase, the teachers develop the PBL activity based on the pre-designed model with required conditions provided by the researchers. After each session, the teachers reflect on the educational practices and improve them for the next session. Qualitative data are collected through observations, teachers' activity plan and interviews, as well as assessment of CT (see Table 1).

Table 1. Phases of the study.

Phase	Description	Data collection	
		Assessment of CT	Teachers' interventions
Pre phase	Teacher develops initial plan based on the pre-designed model. Pupils take the assessment.	Pre-test Pre-survey	Pre-interview Initial plan for PBL activity
Implementation phase	Teacher plans the session in detail. Teacher implements the session. Pupils participate in the session. Teacher reflects the session.	Portfolio Artifact-based interview	Plan for each session Reflective interview
Post phase	Teacher reflects PBL activity Pupils take the assessment.	Post-test Post-survey	Post-interview

4 Discussion

We develop the assessment methods based on the open-ended tests and self-reported survey in [17]. Although their study only measured four components of CT, we aim to measure ten components of CT which are relevant to problem-solving processes introduced by [9]. Pre- and post-test and survey are performed in the beginning and in the end of the maker activity. We add portfolio and artifact-based interview to capture problem-solving process in details [14,18]. The assessments are performed after every session and the results are shared with teachers to improve the following session.

This study provides suggestions for educational practices to effectively develop CT through PBL in the context of maker education. The findings can be applied to teacher education and in-service teachers' professional development for designing and implementing PBL which can enhance CT. As this project is work in progress, International Conference on Informatics in Schools 2020 provides a great opportunity to discuss with experts in the fields and develop the research design to get the best results.

References

1. Becker, S., Jacobsen, M.: Becoming a Maker Teacher: Designing Making Curricula That Promotes Pedagogical Change. Frontiers in Education 5 (2020).
2. Blikstein, P.: Digital Fabrication and 'Making' in Education: The Democratization of Invention. In Walter-Herrmann, J., Büching, C. (eds.) FabLabs: Of Machines, Makers and Inventors, 203–222 (2013).
3. Ge, X., Land, S. M.: A conceptual framework for scaffolding Ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development,* 52(2), 5–22 (2004).
4. Hadad, R., Thomas, K., Kachovska, M., Yin, Y.: Practicing formative assessment for computational thinking in making environments. Journal of Science Education and Technology, 29(1), 162–173 (2020).
5. Harel, I. E., Papert, S. E.: *Constructionism*. Ablex Publishing, New York (1991).
6. Hmelo-Silver, C. E.: Problem-based learning: What and how do students learn?. Educational psychology review, 16(3), 235–266 (2004).
7. International Society for Technology in Education (ISTE) and Computer Science Teachers Association (CSTA): Computational Thinking in K–12 Education teacher resources second edition https://id.iste.org/docs/ct-documents/ct-teacher-resources_2ed-pdf.pdf?sfvrsn=2, last accessed 2020/9/22.
8. Iwata, M., Pitkänen K., Laru, J., Mäkitalo, K.: Exploring Potentials and Challenges to Develop Twenty-First Century Skills and Computational Thinking in K-12 Maker Education. Frontiers in Education 5. (2020).
9. Jeng, H. L., Liu, L. W., Chen, C. N.: Developing a Procedural Problem-solving-based Framework of Computational Thinking Components. In: 2019 8th International Congress on Advanced Applied Informatics (IIAI-AAI) 272–277. IEEE, Toyama, Japan (2019).
10. Mäkitalo, K, Tedre, M., Laru, J., Valtonen, T.: Computational Thinking in Finnish Pre-Service Teacher Education. In Proceedings of International Conference on Computational Thinking Education 2019, 105–107. The Education University of Hong Kong (2019).
11. Savery, J. R.: Overview of problem-based learning: Definitions and distinctions. Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, 9, 5–15 (2015).
12. Selby, C., Woollard, J.: Computational thinking: the developing definition. University of Southampton, The United Kingdom (2013). https://eprints.soton.ac.uk/356481/, last accessed 2020/9/22.
13. Shute, V. J., Sun, C., Asbell-Clarke, J.: Demystifying computational thinking. Educational Research Review, 22, 142–158 (2017).
14. Tang, X., Yin, Y., Lin, Q., Hadad, R., Zhai, X.: Assessing computational thinking: A systematic review of empirical studies. Computers & Education, 103798 (2020).
15. Wing, J. M.: Computational thinking. Communications of the ACM, 49(3) 33–35 (2006).
16. Wing, J.: Research notebook: Computational thinking—What and why. The link magazine, https://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why, last accessed 2020/9/22.
17. Yin, Y., Hadad, R., Tang, X., Lin, Q.: Improving and Assessing Computational Thinking in Maker Activities: the Integration with Physics and Engineering Learning. Journal of Science Education and Technology, 1–26 (2019).
18. Zhong, B., Wang, Q., Chen, J., Li, Y.: An exploration of three-dimensional integrated assessment for computational thinking. Journal of Educational Computing Research, 53(4), 562–590 (2016).