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Developing pre-service teachers' computational thinking through unplugged approaches

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Abstract. Computational thinking (CT) skills are one of the most important skills for solving problems in technology-driven daily life. Although CT skills are an objective in the curriculum framework in education, there are not many research studies related to the development of CT competencies in pre-service teachers that will be used in the process of integrating CT in their learning design. In this study, with reference to the experiential learning framework, we conducted a study related to the design of a new approach to the learning process that is a hybrid of the CT approach. The purpose of this study was to facilitate pre-service teachers to follow the CT module for six (six) weeks. The results showed that the participants were able to develop better CT competence by integrating, justifying, and reflecting CT in their learning processes. This study shows that it is important to provide practical and easy-to-use CT modules on unplugged activities to pre-service teachers, especially for those who do not have basic knowledge related to computing.

INTRODUCTION

Currently, computational thinking (CT) is a competency that is widely discussed in the world of education, especially in the learning process (Angeli, 2020). CT is a 21st century skill that is needed in dealing with current technological developments (Tabesh, 2017). There are many discussions related to the definition of CT as well as indicators related to this ability (Angeli, 2020). Many articles examine the importance of CT capabilities, one of which is related to the importance of CT to underlie artificial intelligence (Agbo, 2019). However, the question of how CT can be effectively injected is still not widely explored (So, 2020).

According to Wing (2008), CT skills are needed in all sciences, both STEM and Non STEM, not only in computer science. Based on this, CT skills are needed in every learning process. In line with this, teachers and prospective teachers play an important role in developing CT through integration through the learning process (Romero et al., 2017). Many countries have incorporated CT into their curriculum (Waterman, 2020). In Indonesia, the independent curriculum includes CT skills through integration into subjects (Indonesian Ministry of Education and Culture, 2021).

In line with this, teachers have an important role in the process of developing CT through integration in the classroom learning process, especially mathematics teachers (Polat, 2021). From the pedagogic aspect, good practices (integration of CT in mathematics subjects) in the independent curriculum will place teachers in new roles and new activities in the classroom. Based on this, it is very important to build the knowledge of teachers and prospective teachers so that it can be ensured that they get comfortable in the process of facilitating integration (National Research Council, 2018). Furthermore, according to Maharani, (2021) it is also necessary to develop the ability of prospective mathematics teachers in integrating CT into. Through reflective activities, special attention is needed in the learning process of prospective mathematics teachers, so as to improve learning designs that are able to facilitate CT integration activities in mathematics subjects in the future (Pewkam, 2022).

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In this study, prospective mathematics teachers are undergraduate students of mathematics education who will later become mathematics teachers in secondary schools. This study also presents literature related to the integration of CT with the unplugged approach. The focus of this study is to analyse the experiential learning framework designed to implement the CT module implementation to improve learning outcomes. Furthermore, this study will discuss experiential learning as one of the pedagogical theories that support learning in fostering the development of CT skills. The main objective of this study is to investigate the effects of the CT module on prospective mathematics teachers' experience-based CT skills.

METHODOLOGY

Research Design

In this study, a case study was conducted to gain an in-depth understanding of the impact of learning mathematics on prospective teachers' CT skills through the application of CT in their learning process. This case study research involves a contextualised real-life case (Yin, 2018). The case in this study is in the form of a concrete entity in the form of a small group (Tadris Mathematics study programme students). The purpose of the case study in this research is to better understand a particular problem (related to the integration of CT in the teaching process) (E.Stake, 1995). In this study, the focus of investigation is the effect of CT module assistance on the development of CT of prospective mathematics teachers through experiential learning.

Participants

The number of participants in this study was 30 prospective mathematics teachers at the secondary school level (mathematics study programme students) with 24 women and 6 men. They are fifth semester students. The condition of the participants at the beginning was that they did not have knowledge of CT skills before carrying out this research activity.

Data Sources

In this study, triangulation of several data sources from several researchers will be used in order to support the findings obtained (Tisdell, 2015). The sources used in this research are interviews, documentation, reflective essays of participants. Semi-structured interviews were conducted with three participants to gain an in-depth understanding of their learning process. Each interview lasted about 50 minutes. The participants were asked to describe their CT learning experience and how useful the CT module was to them in the process of designing lessons.

Data Analysis

This study triangulated data from various sources. The main purpose of the CT module was to provide an opportunity for participants to design a CT-integrated learning process and be able to reflect on their learning process. To examine the participants' learning process and their construction of CT knowledge, the researcher analysed the lesson plans and identified and justified what had been mentioned in their learning designs to determine how they connected CT with mathematics and then categorised their reasoning based on aspects of CT adapted from Marom et al. (2023). The researcher then analysed their reflective essays to identify the CT competencies that they wanted to develop among their students (when they became teachers). The researcher searched for keywords that indicated CT competencies in their reflective essays based on the framework adapted from (Korkmaz, 2017).

RESULTS AND DISCUSSION

The researcher will analyse the design of mathematics learning process that is integrated with CT aspects. The CT indicators that will be used in this study are the definitions proposed by Marom et al. (2023), namely decomposition, patern recognition, abstraction, algorithms and mathematical literacy. Furthermore, coding will be made with two categories depending on the CT aspects that are integrated. The inter-code reliability value for CT aspects is 0.87 which describes almost perfect according to Cohen (1960). Based on the research results presented in Table 1, it was also found that there was an increase in understanding obtained through the CT module, their ability to design the learning process by integrating CT was seen from the learning design (teaching module) they made.

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Based on the teaching modules made from participants that reflected CT aspects, there were only two students whose teaching modules were not related to CT aspects. Given will be given the table:

Table 1. Excerpts of Justification for CT Integration in Teaching Modules

Integration of CT Aspect	Proportion of Participants (30 Participants)	Quotes found in the Teaching Modules
Decomposition	12 (40%)	" ... to decompose the big problem (limit definition), then to understand the limit definition, it will be broken down into smaller problems such as the distance problem at two points, the mapping of each point and others."
Pattern Recognition	12 (40%)	" ... after that I looked for patterns in the simulation process of constructing the limit definition."
Abstraction	20 (66,7%)	"... I constructed the concept of limit using the help of Wolframs Mathematica-based simulation so that I can familiarise myself with certain patterns. By using the patterns that have been found, students are able to predict what components the concept of limit has such as Distance, mapping of each point and others."
Algorithm	20 (66,7%)	" ... After knowing the components of the limit, steps are needed in constructing the limit concept"
Mathematical Literacy	8 (26,7%)	"...After obtaining the components of the limit, then using mathematical concepts (the concept of absolute value) to represent the distance of the function obtained from the approach of the two points"

Furthermore, the researchers categorised based on the justification quotes from the teaching modules made into two categories, namely learning design with one CT aspect and learning design with more than one CT aspect. the results can be seen in the table below:

Table 2. CT Justification in the Participant Teaching Module

Categories	Proportion
Only one CT Aspect in the Teaching Module	12 (40%)
More than one aspect of CT in the teaching module	18 (60%)

Knowledge understanding can occur through two phases, namely the concrete experience phase (CE) and Abstract Conceptualisation (AC) (Kolb, 2015). In this study the participants were active in the offline learning process. CE and AC of Kolb's cycle occur when participants gain CT knowledge through the process of unplugged CT. In the training activities, participants are introduced to the unplugged aspects of CT and then participants carry out practical tasks to be able to gain knowledge by designing lessons (teaching modules) of mathematics integrated with CT for the maple they will teach (CE). Furthermore, the AC phase will occur when the participants apply the CT aspects in the teaching module that has been made. At the end of the learning, a survey was given through google form and the results showed that a large majority of 86.7% of participants aroused their interest in learning related to CT skills. In the next training activity, the participants learnt about the process of CT integration in the context of an independent curriculum (CT-based curriculum) and were given a quiz related to CT skills. In this process, participants felt encouraged to be more active in trying to understand the learning content so as to improve the AC phase. The purpose of this quiz is to measure CT understanding through unplugged CT which emphasises the participants' cognitive process (Yadav, 2022). Participants apply their knowledge in the unplugged process as an asset in the unplugged process.

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The learning activities provided at each stage seem to have enhanced the transformation dimension (RO and AE), where participants transformed their new knowledge through active experimentation (AE). This experiment refers to the learning activities after following each stage of CT Unplugged learning. According to Kolb (2015), it activates the prehension dimension in driving the experience. Furthermore, at the end of the reflective activity they are given guided questions about the activities that have taken place. The purpose of this learning reflection is to be able to assist participants in building meaningful theoretical models based on their learning experiences.

Furthermore, interviews were also conducted with participants to ask them to share good practice experiences in the learning process of designing teaching modules integrated with CT. Participants shared their experiences in connecting Picture Games with CT. "During the training process, I saw that the aspects of CT that I learnt were really able to be applied in the future learning process through the module that I made. Furthermore, the picture games that are useful for sharpening algorithms are able to liven up the learning atmosphere which is fun and at the same time sharpen CT skills" (Interview result with APU).

Overall, the results showed that participants experienced deeper learning related to CT skills and were able to reflect on them through the guiding questions. According to one participant: "After reading the guiding questions, I thought a lot about CT integration. In this reflection process, the questions really helped me to understand this topic" (Interview result from MS).

Furthermore, other participants were asked to reflect on the process of applying CT in solving their problems (in creating teaching modules): "Before I design a mathematics teaching module, I need to understand the important aspects of the topic that I will create (abstraction). After that I plan in my teaching module step by step ... (Algorithm)" (Interview result from DR).

Furthermore, this study investigated the effects of applying Kolb's (2015) experiential learning process in developing CT in prospective teachers across CT modules. Activeness in each of the learning stages promotes optimal learning outcomes. The Prehension dimension emphasises the knowledge transfer process in the learning session. The learning process using the CT module starts with theoretical knowledge related to the unplugged approach. Completion of this prehension dimension activates high-level learning when there is a process of reflection on the knowledge gained in the transformation phase. In this phase, in the first stage of the activity, participants transfer CT knowledge into the mathematics teaching module they create (topic according to participants' choice). Participants expressed their views related to the CT approach into the context in the design of the teaching module created. Participants apply CT aspects in their learning context (AE). In addition, reflection activities at each stage are able to help participants understand what they think, this activity is able to provide multi-perspectives in understanding how they view the learning process during the CT module. so that the CT module must be designed in such a way as to motivate participants to build a higher level of learning, especially in the process of teaching participants who do not have computer programming experience.

The reflection process that has been carried out can be seen as an individual's way of thinking related to their respective learning experiences. According to Dewey (1933), reflection can be described as a person's ability to look back at what has been done in extracting meaning from what has been obtained which will be used as capital in the future. In this study, participants were asked to design a mathematics teaching module integrated with CT. According to Dawson (2006), the level of reflection of prospective (mathematics) teachers can be achieved when a supporting structure is provided. The results of this study are consistent with the literature that the quality of written reflection can improve the predetermined framework. In this study, the CT framework in terms of CT aspects and CT competencies has been described in the CT Module, and there are guiding questions that will be used as an aid in improving the quality of participants' learning reflections. Or in other words, experiential learning through the CT Module shows that the concept of CT can be introduced to prospective mathematics teachers with an appropriate sequence of content arrangement (starting from the Unplugged approach), this refers to the initial ability of the activity participants (prospective mathematics teachers). The structural arrangement of the CT Module used aims to improve understanding related to content knowledge and transform it into pedagogic knowledge.

CONCLUSION

According to (Yadav, 2022) the lack of understanding of prospective teachers related to CT can be seen as a rudimentary mathematical process. In this study, in line with the study conducted by Caeli (2020), the key component in building the capacity of prospective teachers is to be able to demonstrate the relevance of CT in their

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classroom with the Unplugged approach. Based on this, it is appropriate for the module with an unplugged approach to introduce CT to prospective teachers (low level of programming understanding).

This CT module is able to facilitate CT learning for prospective mathematics teachers and is able to assist in the process of integrating CT into future learning processes in the independent curriculum. The tasks and practices in the learning process are able to provide support for prospective mathematics teachers with a low understanding of computer programming. Using the training (learning) design used showed that there was considerable improvement in the conceptual understanding of CT understanding. The results of this study indicate that the learning outcomes using this CT module correspond to the reinforcement of the well-known pedagogical framework of Kolb's experiential learning cycle. This experiential learning cycle, using the CT module, was able to increase the prospective teachers' knowledge related to CT. The justification found in the teaching module is an indicator in showing their ability to integrate CT into the learning process. In addition, the CT module is proven to be able to provide assistance in supporting the capacity of prospective mathematics teachers by focusing on: (1) development of CT approach with Unplugged approach, and (2) practice and reflection of CT learning based on their experience.

In this study, the empirically validated significant contribution is that the CT module can be used as an alternative aid in improving the CT ability of prospective mathematics teachers. This can be obtained by focusing on theory and practice through an unplugged approach supported by Kolb's experiential learning. This CT module contains the main features of teacher education that are very helpful by making connections between theory and practice, both practical design and integration of learning reflections with the aim of being able to prepare prospective mathematics teachers in the process of integrating CT in mathematics subjects. The general goal in preparing prospective teachers is to foster individuals who are ready for the profession who will be able to apply various good practices in meeting the needs of future learners in real terms. In addition, to achieve this goal, each prospective teacher needs to balance theoretical building and the ability to implement evidence-based learning, so that it is very important in the training of prospective teachers in preparing for the future teaching process.

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