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Computational Thinking in Mathematics Learning Task Design: Stating Goal, Designing, and Plug In, of Indonesian Pre-service Math Teachers

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Abstract. This study aims to describe the pedagogic knowledge of prospective mathematics teachers in making mathematics problem-solving problems with the concept of Computational Thinking (CT). This study uses an exploratory, descriptive quantitative research involving 95 prospective mathematics teacher students from various regions in Indonesia. The subject is given a job to design CT assignments in mathematics learning. Data obtained from performance sheets in the form of assignments made by prospective teachers. The data were analyzed using the question feasibility performance sheet due to design principles, the results of assignment-based interviews, and field notes. Data analysis was carried out by triangulation by combining the results of the analysis of performance sheets, interviews, and field notes, the results obtained from the performance of prospective teachers, design assignments by paying attention to design principles. Assignments are made accompanied by an answer key with concepts that support CT. In this case, the study results found the pedagogic knowledge of prospective mathematics teachers when making questions by paying attention to setting goals, designing, and plugin. There are significant differences in the criteria for each CT component seen from the level of knowledge of high, medium, low sig values of 0.000, respectively; 0.002; 0.004, and 0.008 means that there is a significant difference between each group.

Key word: computational thinking; task design; mathematics learning.

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INTRODUCTION

Technology and information are developing very rapidly are marked by the development of technology and information. This situation requires the world of education to be able to design curriculum and technology, and knowledge is developing very rapidly learning, to being able to create students who have skills and can be globally competitive. One of the skills that can support the development of technology and information is thinking computationally. Making students capable of computational thinking, of course, begins with a teacher who can design learning devices to direct students to computational thinking skills.

A teacher's academic ability is also required to keep up with developments in technology and information. Teachers must be more prepared than their students. Before exploring technology, prospective teachers must master two knowledge, namely, Pedagogical Content Knowledge (PCK), which is an integral mixture based on a coherent and generative understanding of mathematical ideas that make up the curriculum (Mishra & Koehler, 2006) (Aminah & Wahyuni, The ability of pedagogic content knowledge (PCK) of mathematics teacher candidate based on multiple intelligent, 2019).PCK grows when a teacher can transform their subject knowledge into suitable teaching methods. There is a strong relationship between what and how teachers know about mathematics and what happens during learning.

A teacher must design a learning device plan so that the desired goals are achieved (Aminah & Wahyuni, 2019). This ability is commonly called Pedagogical Knowledge (PK), which is in-depth Knowledge of how to teach teachers in the classroom or the science and art of teaching children to achieve learning goals so that learning management can be carried out correctly (Mishra & Koehler, 2006). Pedagogical Knowledge is divided into two, first is specific pedagogy, namely, pedagogy that can only be used by certain content, and second is general pedagogy that can be used by various content or learning materials (Cox & Graham, 2009).

The lesson plan created by the teacher can be used for the duration of one meeting or even more. Learning goals are developed from competency standards to achieve essential competencies and learning objectives. Teaching without written preparation will result in ineffective learning in the classroom because teachers do not think in detail about what and how the learning process occurs (Joseph & Leonard, 1988). The teacher's ability to develop lesson plans requires knowledge of learning theories, models, strategies, learning methods, and an understanding of evaluation tools. The power in choosing learning theories, models, systems, learning methods, and question indicators can determine what kind of learning the teacher wants to create so that learning outcomes that include affective, psychomotor, and cognitive aspects are achieved as what we wish to (Aminah, Sukestiyarno, Wardono, & Cahyono, 2020).

The importance of content development, selection, and ordering of instructional tasks to fulfil certain instructional results is contained in the aspects of Specific Content Knowledge (SCK) (Ward P. , 2013). The ability of teachers to select and sort instructional tasks can be distinguished by effective and ineffective teachers (Ayvazo & Ward, 2011; Kim, 2015; Kim & Ko, 2020). Rink identifies four categories of instructional tasks in evaluating teachers in developing content abilities: (a) informing initial sequential assignments for teaching, (b) extending extended assignments by increasing or decreasing complexity or difficulty relative to previous assignments, (c) refining assignments with improving and focus on the quality of performance, and (d) apply/assess tasks used to implement performance in-game settings or assess student performance abilities (Rink, 2020). Evidence shows that SCK is not obtained from a history of activity (Tsuda, Ward, & Li and K, 2019; Ward, Tsuda, Derven, & Devrilmez, 2018).

Assignments that are designed should pay attention to the elements of task design to evaluate the adequacy of the tasks designed by the teacher. There are five elements identified in making assignments, namely the context of the task, language, structure, distribution of content selection, and the level of interaction of the participants (Barbosa & Elivia, 2013, as cited Sullivan, Knott, & Yang, 2021). Tasks created to achieve learning objectives must have assignment writing criteria. Ron, Zaslavsky and Zodik describe a three-stage task design process which includes: (1) Stating goals and linking tasks to those goals, (2) Designing general tasks that address objectives, (3) selecting specific examples to "link" the task general (Ron, Zaslavsky, & Zodik, 2013). This step can be seen in the following figure.

Figure 1. The Design Task Process

The image describes the stages of the task design process. (1) Stating goals and linking assignments to these goals, teachers' knowledge about pedagogics is developed to link the assignments made to the learning objectives at each meeting. (2) the following process is to design general tasks that discuss goals. For example, the task contains learning material objectives and cognitive goals. (3) Connecting, the teacher must be able to design tasks by connecting subject matter with appropriate examples.

The process of designing tasks focuses on adaptation describing suggestions in text to inform instruction (Knot et al., 2013 as cited Ainley & Magolinas, 2021). This process involves both components, task design and consideration of the learning environment, namely: (1) Choosing lessons from the text and identifying critical mathematical understanding or ideas, (2) Writing mathematical ideas as generalizations, (3) Deciding whether essential understandings require justification, (4) Finding or designing assignments or task sequences that encourage exploration of ideas, (5) Writing questions for students that can encourage them to generalize ideas (Ainley & Margolinas, 2021).

Making problems in learning mathematics in exploring the knowledge that will be aimed at needing to pay attention to the types of questions, whether text-based or queries that contain algebraic numerical calculations. For text-based problems, three interrelated design principles should be considered: (1) The nature and structure of the task. (2) The academic/didactic objectives of the design task objectives. (3) The intended/implemented mathematical activity, the ability and the opportunity to study. The relationship between designing mathematics assignments, teachers, and students is significant at every stage. Because they both contribute to the context of students' mathematical activities

(Watson & Thomson, 2021).

The design principle deals with three aspects of the nature and structure of the assignment. (1) the type of text material in which the assignment is found, (2) authorship and authority, and (3) the content of the mathematics assignment (Watson & Thomson, 2021). The pedagogy of a task also influences how the job can be designed, considering how cultural differences in design affect goals, how learners are made aware of plans, how developers ensure coherent goals in the set of tasks, and how new knowledge is integrated with existing knowledge. Student activities also become a consideration in designing assignments.

Technological developments that have an impact on learning require students to be able to think quickly. Student activities in education are always associated with technology and student thinking activities which are the hope of being able to think computationally. Teachers and prospective teachers must be able to package learning that involves student activities. Question making should also be linked to real-life problems. The use of technology to complete assignments also needs to be considered to be engaged in mathematical modelling activities (Cahyono & Sukestiyarno, 2020). To prepare prospective teachers who can include technology in their learning, universities that produce teacher candidates must immediately consider post-industrial perspectives related to curriculum surgery and prepare 21st-century teacher candidates. Teaching, learning, curriculum and research need to be carried out and continue to be supposed to graduate. with the necessary competencies to support lifelong learning, including computational thinking skills that must be attached to student-teacher candidates, this is to prepare prospective teachers to be able to implement Computational Thinking (CT) in classroom learning.

CT is an approach to problem-solving for designing systems and understanding human behaviour that leads to the basic concepts of computing (Wing, 2011). CT scan also is seen as algorithmic thinking using principles from computer science as a structural and metaphorical framework (Shodiev, 2013). Hoyles and Noss define CT as an abstraction that requires decomposition algorithmic thinking and pattern recognition (Hoyles & Noss, 2015). However, in classroom learning, in addition to cognitive assessment, affective and psychological assessments are needed. For that to support computational thinking, creative thinking is also required. So teachers need to design assignments to achieve these goals.

CT research in mathematics learning is still being studied. It becomes a reference material, research that develops a pedagogic framework for exploring CT, from research produced by CTPF includes four pedagogical experiences: (1) unplugged, (2) tinkering, (3) making, and (4) remixing (Kotsopoulos, et al., 2017). In contrast to the research results of Yadav et al., which addresses primary computational thought constructs, including algorithms, abstraction, and automation. By discussing how these ideas relate to current educational reforms, such as the Common Core and Next Generation Science Standards and providing specialized tools that allow teachers to embed CT ideas in their K-12 classrooms, the results suggest computational thinking ideas. Described is the key to moving students from simply being technologically literate to using computational tools to solve problems (Yadav, Hong, & Stephenson, 2016).

Research to examine how the PCK preservice set by the teacher is defined as task selection, task representation, and task adaptation and the use of different instructional tasks as a function of content knowledge (CK) developed through introductory physical education content courses (Insook, 2020). This study provides significant evidence to support the critical role of solid CK and its impact on early PCK development and the use of instructional tasks in teaching essential content.

The research that has been described above is reference material. Besides that, the researchers argue that CT can be used in learning outside of computers. So to be implemented in other disciplines, strong knowledge from teachers is needed regarding the CT component. However, from previous research, it has not been seen that the study designed CT assignments in mathematics learning. Students' mathematical abilities in supporting CT can be explored through projects that are packaged by the teacher. Tasks that are made should be based on the principles of task design. In this study, prospective teacher students' research results in designing CT assignments in mathematics learning with design principles: properties and structure, educational objectives, and activities.

Problem of Research

Excerpts from the theory and some previous studies reveal that exploring CT can be done by developing pedagogics. CT can be used in knowledge other than computer science. Basic content can be developed via PCK. Prospective teachers must have pedagogic knowledge, content, and assignment design principles. Meanwhile, to produce learning objectives achieved, it is necessary to know about designing tasks according to learning objectives. This study will describe the activities of prospective teachers in making mathematical problem-solving problems with the component of CT. Therefore, the limitation of this research is computational thinking in mathematics learning, while the research problems that will be explored are: (1) How are the questions made by prospective mathematics teachers based on the principles and criteria of task design? (2) Are there differences in the computational thinking ability of prospective teachers in terms of high and low cognitive criteria?

METHOD

The method used in this research is descriptive quantitative.This study aims to determine the activities of prospective mathematics teachers in making mathematical problem solving tasks with the concept of Computational Thinking. This research was conducted on student teacher candidates from 2 different universities in Indonesia. The two universities were selected from areas in the island of Java which have different ethnicities and have a mathematics education study program, with the aim of seeing the process of designing CT assignments in mathematics learning from scattered subjects. Thinking processes produced by students who have different characters.

Data Collection

The data in this study are documentation obtained from the work of prospective teachers in the form of written descriptions on the performance sheets of the prospective mathematics teachers designing CT assignments in mathematics learning, dissertations with assessment scores, performance recordings in the form of video and audio, recorded interviews between researchers and selected subjects in the form of video and audio, as well as field notes in the form of research notes that occur during the research process. The research instrument in the form of a performance appraisal sheet is used to analyze the flow of designing assignments to measure students' mathematical abilities in supporting CT, while interviews are used to explore processes that require clarity from visible performance sheets and observations.

Data Analysis

The data obtained from the teacher candidates' performance results, performance appraisal notes, interview notes, and field notes were then analyzed using a retrospective analysis combining several data sources. Comparative analysis is used to analyze the different thought processes carried out by each subject (Corbin & Strauss, 2012). From the study carried out, the research conclusions were drawn from the research findings.

Procedure

The research process was carried out in two stages. The first stage is selecting subjects as many as 95 prospective mathematics teacher students are then given the task of making questions to support computational thinking. The second stage analyzes the questions and answers created by prospective teachers. The data were analyzed with the guideline of the table list of task design principles to obtain data on how their thinking activities were in designing tasks and analysis of the thinking process in making answer keys. From the results of recording to observe the problem-solving procedure, then an interview was conducted.

Results

The process of selecting the performance of the student mathematics teacher candidates obtained 30 students who submitted their assignments. Thus the subjects in this study amounted to 30 issues, with details of 12 students from the city of Kediri and 18 students from Cirebon. The issue has mastered designing assignments to achieve the goal of measuring students' mathematical abilities in supporting computational thinking. Still, several issues are of concern, seen from the performance sheet he has made, and will be used as research subjects, In this case, the researcher names the first subject 1 after this referred to as S1, the two issues 2 starting now referred to as S2.

First Data Analysis Tes Item Based Design Task (S1)

In the collected documents, S1 seems to be making tasks related to daily life. S1 makes questions that are not routine and open-ended. Following are the results of S1 performance in designing tasks to achieve mathematical thinking in supporting CT.

Jika anda mempunyai dua lembar kertas karton masing-masing berukuran 15 x 45 cm dari Selembar karton akan dibuat sebuah wadah berbentuk tabung tanpa tutup, dapatkah anda memberikan ide dengan model tabung yang berbeda. Jika alas tabung pertama 15cm, sedangkan tabung kedua alasnya 45cm, samakah ukuran volume tabung tersebut? Misalkan kedua tabung tersebut akan disimpan kosmetik (lipstick anggap berbetuk tabung) yang panjangnya 12 cm dan alas bawahnya berbentuk lingkaran dengan jari-jari 1,5 cm. tiap wadah tersebut mampu menampung berapa lisptiks?

In English:
Suppose you have two sheets of cardboard, each measuring 15 x 45 cm. A sheet of cardboard will be made of a tubular container without a lid. Can you give ideas with different tube models? If the base of the first tube is 15cm, while the second tube has a 45cm base, is the volume of the tube the same? Suppose that the two tubes will be stored cosmetics (assume the lipstick is in the form of a tube) which is 12 cm long, and the bottom base is circular with a radius of 1.5 cm. How many lipsticks can each contain?

Figure 2. Tasks created by S1

The design of the assignment that has been made by S1, it appears that there are questions that invite students to encourage chlorinating ideas, develop ideas, and ask students to think abstractions to become mathematical sentences in finding solutions to problems they face. The purpose of making the assignment can be seen in the following interview excerpt.

S1: "The purpose of these questions, students can implement the material for building 9 classrooms related to the conditions of everyday life. The knowledge to be achieved is expected to be able to think abstractional, to be able to make completion steps, to be able to make patterns, to be able to complete small tasks to get big task solutions."

This interview is a reinforcing material to state that S1 has designed the task by the principles of design tax theory, including the "Setting Goal" stage of S1 making questions to achieve learning objectives and exploring the mathematical abilities of the intended students. The "Designing" stage of the assignment designed by S1 encourages students to explore their ideas. This can be seen from the questions that are intended to relate to everyday life. In the "Plug-In" stage, the example given uses the problem of building spaces in everyday life, which can arouse student interest and connect according to the learning material. There are also questions to explore students' creativity and thinking patterns, as seen from the sentence *"Can you give ideas with different tube models?"*.

Second Data Analysis Tes Item Based Design Task (S2)

The following document analyzes the results of S2 performance in designing assignments, which are presented in Figure 4 below.

Kerjakan permasalahan berikut dengan jelas dan tepat.
Sebuah gedung tinggi terlihat dari pegunungan yang segar, seorang anak dengan tinggi badan 160 cm mengamati puncak sebuah gedung dengan sudut elevasi 45°. Kemudian dia berjalan sejauh 16 meter mendekati gunung. Diposisi ini, anak tersebut mengamati puncak gedung kembali dengan sudut elevasi 60°. Bisakah anda merasakan bahwa anda benar-benar dalam keadaan ini, dapatkan anda membuat sketsa pada kondisi ini?. Jika anda dalam kondisi ini dapatkah anda menghitung tinggi gedung tersebut, berikan penjelasan dengan perhitungan yang tepat.

In English.
A tall building seen from the fresh mountains, a child 160 cm tall observes the top of a building with an elevation angle of 45 degrees. Then he walked for 16m toward the mountain. In this position, the child observes the top of the building again with an elevation angle of 60 degrees. Can you feel that really in this state? Can you sketch this condition? If you are in this condition, can you calculate the height of the building? Explain with the correct calculation.

Figure 3. Tasks created by S2

In the design of the assignment made by S2, some questions invite students to encourage chlorinating ideas, develop ideas, and think creativity that asks students to use other alternatives in finding solutions to the problems they face. These circumstances made me want to do an in-depth interview.

Q: "Why do you invite students to really feel that you are in that condition?"

S2: "I hope, by imagining this situation, it will lead to students' abstraction thinking so that they can draw a sketch into a mathematical form."

Q: "In the second problem, you invite students to be able to count and imagine in the conditions described in the assignment. What do you think?"

S2: "In this case, I invite students to be able to think in solving small parts of complex problems, and be able to think step by step to solve problems."

The dialogue that has occurred provides information that S2 has tried to design the task with the tax design criteria. The language structure is easily understood by students. The command problems that must be resolved by students are clearly measurable and are by the learning objectives, namely the use of trigonometric rules in everyday life problems.

The process of the design stage has been carried out by S2. The interview can be explained when the S2 Stating Goal stage focuses on thinking about the questions that are made by the trigonometric learning material. The set of "designing" questions is designed with particular objectives in mind. That is, students can use trigonometric rules in the problems of everyday life. The final stage, namely "Plug-In" S2, connects the example using issues in everyday life that are easily understood by students and reflects that the problem can use more than one method.

Analysis data Indicator Computational Thinking

The following will explain indicators of computational thinking, can be seen from table 1.

Tabel 1. Indicator Computational Thinking

Indicator	Competensi			
	High	Medium	Low	Mean
Decomposition	2.80	2.78	2.75	2.78
Algoritm	3.25	3.00	2.85	3.03
Abstraction	3.40	3.35	3.29	3.35
Generalization	3.30	3.23	3.18	3.24
Verification	3.25	3.00	3.15	3.13
Average	3.22	3.11	3.03	3.12

The table provides assessment data for each component in CT. It can be seen in the table that the highest average is in the abstraction component of 3.40, while the lowest is the decomposition component of 2.78. The other components are included in the good interpretation with an average above 3.00. Furthermore, the data were analyzed using SPSS one way ANOVA calculations, to find out whether there were differences in the ability of the CT components between groups. Previously, the observation data had been converted into calculations into ordinal data. All data have gone through the normal and homogeneous conditions. More details can be seen from the following table 2.

Tabel 2. One Way Anova Calculation Data

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Decomposition	Between Groups	128.707	2	64.353	31.719	.002
	Within Groups	34.491	17	2.029		
	Total	163.198	19			
Algoritm	Between Groups	32.968	2	16.484	9.021	.002
	Within Groups	31.062	17	1.827		
	Total	64.030	19			
Abstraction	Between Groups	157.903	2	78.951	36.169	.008
	Within Groups	37.108	17	2.183		
	Total	195.011	19			
Generalization	Between Groups	29.915	2	14.957	7.796	.004
	Within Groups	32.617	17	1.919		
	Total	62.532	19			
Verification	Between Groups	48.446	2	24.223	41.046	.000
	Within Groups	10.033	17	.590		
	Total	58.479	19			

From the table above, it is explained that when the sig value is less than 0.05, it accepts H1. The five TPCK indicators above have sig values of 0.000, 0.002, 0.004 and 0.008 <0.05%, respectively, meaning that there is a significant difference in average seen from all groups. Overall the elements on the CT indicator have reached completeness.

Discussion

Prospective teachers who have selected subjects in this study have used the process principles of task design, stating the goal, designing, and plug-in stages (Ron, Zaslavsky, & Zodik, 2013; Sullivan, Knott, & Yang, 2021). However, the two subjects were selected in different processes. The process of the stages of "Statting Goal." Subjects have pedagogic knowledge in making evaluation tools, and participants appear to link the tasks they make according to learning objectives and choose sample questions according to daily life problems. S2 makes problems of everyday life related to trigonometric material. This condition invites students to get used to thinking creatively by asking non-routine questions following their creative thinking skills (Sukestiyarno, Mashitoh, & Wardono, 2021).

At the stating goal stage, the participant Pedagogical Knowledge (PK) appeared. It should be noted that PK is divided into 2, namely specific pedagogy and general pedagogy. Where specific pedagogy can only be used by certain content and general pedagogy that can be used by various content or learning materials (Cox & Graham, 2009, as cited Candra, Soepriyanto, & Prahendriono, 2020) at this stage, the participant can make questions by showing the cognitive objectives and the objectives of the learning material.

The process of the stages of "Designing" in designing assignments, content knowledge here emphasizes making answer keys. The answer key that is made is analyzed to see the thought work process of the participant. The results of S1 performance in making questions vary widely. It has been seen that the knowledge of the content to be addressed, the examples made are by the material taught at the age of junior high school learners. It appears that it relates everyday life to the material being studied. The knowledge extracted is aimed at making a score according to the ability to be explored. Content knowledge about the subject matter, related to the content that the teacher must teach. (Insook, 2020; Chai, Koh, & Tsai, 2013), the material must be mastered by a teacher both in teaching the material and in designing assignments.

The research subjects here can connect existing problems to the subject matter. This process enters the "Plug-In" stage. Participants try to provide problems that invite students to imagine and feel in that situation. Inviting students to think abstractly. Abstraction is a process of making artifacts easier to understand by reducing the detail and number of unnecessary variables and leading to more accessible solutions. Before thinking about abstractions, the previous students were invited to do mathematical literacy (Humpreys, 2015).

Participants in pedagogic knowledge can be seen from how to make questions. Meanwhile, content knowledge is implied in making the answer key. Making the answer key for all subjects provides two answer key choices. This activity gives special attention that the subject can think creatively. Creative thinking is the ability to consider things in new ways. Creativity can find new solutions, new problems, and old problems to be well researched. Someone's creativity to find patterns of thinking, to find alternatives when experiencing obstacles. someone's creativity to find patterns of thinking, to find alternatives when experiencing obstacles (Dal, et al., 2016; Leong, 2013).

The answer key that is made invites students to think mathematic, which varies. The activity is taken from interviews that have occurred. S1 explores students to think abstraction, logarithms, decomposition, creatively. S2 explores students to think abstraction, logarithmic, decomposition, debugging, creative thinking. Everything that is explored is included in the ability to think to support computational thinking. The foremost vital concepts and skills in computational thinking include abstraction, algorithms, automation, decomposition, and generalization (Bacconi, 2016). *Computational Thinking (CT)* is a thought process involved in formulating problems and expressing solutions (Selby & Woollard, 2014). Many researchers revealed the components of CT. Think abstraction, Algorithms, Automation, Problem Decomposition, Parallelization, Simulation, CT support components provided by Bar Stephenson (Barr & Stephenson, 2011). Thinking Abstraction, Algorithms, Decomposition, Debugging, Generalization are the supporting components of CT as expressed by Angie (Angeli, et al., 2016).

CONCLUSION

Based on the explanations, data analysis, and discussion described above, this study concludes that teacher candidates use their knowledge and pedagogical content, which is reflected in the assignment design. Assignments are designed to take into account the principles of task planning, design, and plug-in processes (Ron, Zaslavsky, & Zodik, 2013). Learning objectives, as well as cognitive goals, are considered in creating assignments. Problems in everyday life are used as examples. The problem invites students to do mathematical literacy and make mathematical patterns from the problems given. Creativity is raised in making questions. The hope is that students can find new ways of thinking when they encounter obstacles. There are significant differences in the criteria for each CT component seen from the level of knowledge of high, medium, low sig values of 0.000, respectively; 0.002; 0.004, and 0.008 means that there is a significant difference between each group.

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