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Computational Thinking Analysis of 21st Century Professional Teacher Candidates In Solving Math Problems Viewed from The Four Foundations of CT

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ABSTRACT

Computational Thinking (CT) is a further development which is the latest innovation in mathematical problem-solving skills. Four foundations of CT make it easier for someone to solve problems effectively, efficiently, and optimally. This mixed methods research with an embedded design. Quantitative data were collected using tests and qualitative data through written interviews and an overview of the prospective teacher's thought processes in answering tests. The sample that became the research subject was selected using the purposive sampling method by selecting 28 pre-service teacher's mathematics in Professional Teacher Education (PTE) who attended CT lectures. The object of this research is the 4 CT foundations of prospective teachers in solving math problems. This study describes how CT skills solve problems. The test results show that the percentage of correct answers for each of the four CT foundations is more than 80%. It can be concluded that the knowledge and understanding of Computational Thinking for 21st-century professional teacher candidates in terms of 4 CT foundations are categorized as "very high". Based on the description of the student's answers, it was also concluded that the CT foundation is indeed the basis for thought processes in solving problems. It is the advantage of Computational Thinking.

Keywords: Computational thinking, Foundations of CT, Professional teachers

INTRODUCTION

The government has redeveloped the curriculum from Curriculum 2013 to an Independent Curriculum. The Independent Curriculum was introduced in 2022 to overcome the impact of the covid-19 pandemic (Indarta et al., 2022; Kemendikbudristek,2022). The impact of the covid-19 pandemic is the learning lag during the pandemic (Wiguna & Tristaningrat, 2022). The Independent Curriculum is a new Ministry of Education, Culture, Research, and Technology policy of the Republic of Indonesia to realize an innovative learning process and meet students' needs (Rahayu et al., 2022). Problem-solving ability is important in facing global competition in the 21st-century (Anita et al., 2021; Aziz, 2022; Hizqiyah et al., 2022). The Independent curriculum being developed is adapted to the 21st-century education paradigm (Indarta et al., 2022). Learning using an Independent Curriculum follows 21st-century learning, which shows that problem-solving ability is one of the abilities that must be possessed to be ready to face the progress of the times (Ardianti & Amalia, 2022; Fitriyah & Wardani, 2022).

Problem-solving is an individual's ability to think complexly using a concept or idea to

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solve a problem (Armiati et al., 2018; Budi & Izzati, 2021). Problem-solving ability is very important because a person with good problem-solving ability can achieve the goals he wants more easily (Kenedi, 2018; Nuraeni & Rosyid, 2019). The importance of problem-solving ability can also be seen from the learning objectives in the independent curriculum that problem-solving ability is one of the abilities that must be achieved in mathematics learning objectives (Kemendikbudristek, 2022). There are new things related to solving this problem. Problem-solving is generally aimed only at finding solutions without clear boundaries or criteria. The Independent Curriculum explains that solving mathematical problems focuses on finding solutions and emphasizes how one's thinking processes find effective, efficient, and optimal solutions, both in terms of processing time and the accuracy of solutions. It is what is meant by "Computational Thinking", which is shortened to "CT" (Aziz, 2022).

The concept of Computational Thinking (CT) was first introduced by a mathematician named "Seymour Papert" in his book "Mindstorm" in 1980 (Angeli et al., 2016). Computational Thinking comes from a method commonly used by computer scientists in solving problems, but CT's way of thinking enters the world of education (Olimpo, 2017). Computational Thinking is a step used to find alternative solutions to a problem from input data by using an algorithm to implement software techniques in programming (Anistyasari et al., 2020; Cahdriyana & Richardo, 2020). Computational Thinking does not mean thinking like a computer but computing in terms of thinking to formulate problems in the form of computations and develop computational solutions (Augie, 2021). Computational Thinking in education means that through computational abilities, humans can solve math, computer, and everyday life problems (Fitriani et al., 2021). Computational Thinking helps anyone think in a structured way to solve problems (Angraini et al., 2022).

In the world of education, the definition of CT is the systematic thinking process of data processing or information in formulating problems and choosing strategies to find effective, efficient, and optimal solutions (Natali, 2022). There are three main things in the definition of CT, namely: (1) issues/problems, (2) effective, efficient, and optimal solutions, and (3) information processing agents. Information processing agents in CT are humans or computers (Wing, 2017). In the world of education, what is meant by an agent processing information is a teacher. Focusing on the world of education, it is only appropriate that 21st-century professional teachers own this CT ability. Professional teachers in the 21st-century must master CT because CT is considered a future teacher skill (Bower et al., 2017; Kamil et al., 2021; Ung et al., 2022; Dong et al., 2023; Cheng et al., 2023; Astuti et al., 2023; Lestari & Roesdiana, 2023). It was also clarified that the inclusion of material on CT in the curriculum in the classroom is a demand of society today and in the future (Hsu et al., 2018). Computational Thinking is also a must for students because it is an essential skill for 21st-century students (Yadav et al., 2016; Maharani, A., 2020). Professional teachers and students must also have Computational Thinking (Cahdriyana & Richardo, 2020; Fitriani et al., 2021).

Computational Thinking aims to solve problems systematically using the concept of thinking (Fauji et al., 2022). In Computational Thinking, problem-solving activities can be found through the characteristics or foundations of CT. This CT foundation is a way of thinking to solve problems with effective and efficient stages (Anistyasari et al., 2020; Fitriani et al., 2021). Many sources state there are 5 to 8 CT foundations. However, in general, there are four essential foundations in computational thinking (CT), namely: (1) decomposition, (2) pattern recognition, (3) abstraction, and (4) algorithms. These four CT foundations can also be considered basic techniques for solving mathematical problems (Apriani et al., 2021; Budiarti et al., 2022).

Decomposition solves mathematical problems by breaking down, sorting, or dividing complex problems into smaller sub-parts of more specific problems. Pattern recognition is solving math problems with the technique of observing or analyzing, or looking for patterns

or similarities between the questions to be solved with previous similar or similar questions or patterns obtained from observing each type of information in one problem, then using solutions or modifying existing solutions of similar problems to solve new problems. Abstraction is solving a mathematical problem by eliminating the information in the problem, where information considered irrelevant or useless in finding a solution to a problem is ignored. In contrast, the critical part of the information is used as a mathematical model to find a solution to the problem. The foundation of "algorithmic" thinking is a person's thought process in designing sequential logical steps according to problem boundaries to solve mathematical problems. (Kamil et al., 2021; Supiarmo et al., 2021; Astuti et al., 2023).

Before CT was introduced in Indonesia, abstracting ideas from math problems was an unavoidable (important) thought process when someone solves math problems (Helma & Edizon, 2017). Since CT was introduced, from the four foundations of CT, abstraction has become the most critical thought process among the other foundations (Powers et al., 2020). It is because abstraction is also used in defining patterns or pattern recognition. The foundation of the algorithm is also an abstraction of a process that adjusts the information in the problem, executing sequential steps to solve the problem (Yadav et al., 2016; Wing, 2017; Maharani et al., 2021). We can assume that the CT foundations are interconnected.

Professional teacher candidates must work on math problems based on 4 CT foundations so that the solutions obtained are effective, efficient and optimal in process and results. It is what the world of education expects, moreover, many students complain that it is challenging to solve problems or that some students successfully solve math problems but take a long time (Utari et al., 2019). Indeed, these students also do not know and understand the four foundations of CT. Therefore, CT plays a vital role as an innovation in solving mathematical problems. A person's ability to solve "Higher Order Thinking Skills" (HOTS) questions increases by 81.8% (Chahyadi et al., 2021) with CT. If the teacher does not know, understand, and apply the four foundations of CT in solving math problems, then the students he teaches will also have more difficulty answering questions.

Based on the previous explanation, to solve the problem, the Computational Thinking Foundation must be appropriately applied. Computational Thinking will lead to producing an appropriate solution. The 21st-century Professional Teacher Candidates should be able to solve mathematical problems with Computational Thinking skills through the CT foundation. This ability of CT is also considered a further development or the latest innovation of problem-solving ability because CT is a thought process that makes it easier for someone to make problem-solving decisions (Julianti et al., 2022). This research aims to describe how "Computational Thinking" (CT) for 21st-century professional mathematics teacher candidates solves math problems when viewed from the four foundations of CT.

METHODS

This type of research is mixed research (mixed method research). Mixed research combines quantitative and qualitative research to complement or refine research results and discussions (Mustaqim, 2016; Ashel & Riandi, 2022; Shoddiq et al., 2022). The mixed method research design used is a concurrent embedded/nested design (concurrent/nested combined design but not balanced). In this design, data collection methods are carried out at the same time, both quantitative and qualitative data methods, but one method (quantitative or qualitative) dominates (primary) while the other is embedded or nested in or within it (secondary). The research questions to be answered by embedded methods are secondary or address specific subtopics connected to general research questions (Azhari et al., 2023).

The population of this study were all students of the 2023 pre-service teacher professional education program at Padang State University. The sample or research subject

was students in the field of mathematics who took a computational thinking course. The sample was selected using a nonprobability sampling technique with purposive sampling. This sampling technique is based on considerations or research objectives (Belviyani & Utami, 2017). This study aims to identify, examine, and describe the computational thinking (CT) abilities of 21st-century professional teacher candidates in terms of 4 CT foundations, both quantitatively and qualitatively. The object of research is computational thinking (CT) in terms of the four foundations of CT. The sample or research subjects were 28 students in the field of mathematics studies who came from the computational thinking course in the pre-service teacher professional education program in 2023. The results of this study only apply to samples or research subjects because the samples were taken using a non-probability sampling technique.

Data collection instruments used tests for quantitative research and non-tests for qualitative research. A mixture of data collection methods aims to obtain more in-depth data related to research questions that cannot be revealed based on only qualitative or quantitative data (Creswell, 2017). There are two questions in this study, namely primary questions and secondary questions. The primary research question is, "What are the results of the computational thinking (CT) test for prospective professional teachers in the 21st-century". The secondary research question is "How is the description of students' thinking processes in solving questions based on the CT foundation (minimum)". Secondary questions support the results of quantitative research.

The primary research question was answered using a quantitative data instrument in a test consisting of 4 questions. Each question has a (minimal) foundation of computational thinking to find a solution. Someone may work on a problem based on 1, 2, 3, or 4 foundations, but in a problem, it has been determined which computational thinking basis is used to solve the problem. Question 1 measures the foundation of "decomposition". Question 2 measures the foundation of "pattern recognition". Question 3 measures the foundation of "algorithms". Question 4 measures the foundation of "abstraction". The percentage that answered correctly on each question was calculated based on the test results. Some indicators of student answers are: (1) correct answer with valid reasons, (2) correct answer without valid reasons, (3) wrong answer, and (4) no answer. The percentage of test results is grouped into five categories, which are $80 < very\ high \leq 100$, $60 < high \leq 80$, $40 < enough \leq 60$, $20 < low \leq 40$, and $0 < very\ low \leq 20$ (Novita & Hidayati, 2022). Answers in this category are only correct answers accompanied by valid reasons. The secondary research question was answered using a qualitative data instrument in the description of the test answers reviewed based on the (minimum) CT foundation that is mandatory in the answers of pre-service teachers and accompanied by written interviews contained in the questions that ask for reasons for answers so that the results of this description become qualitative data.

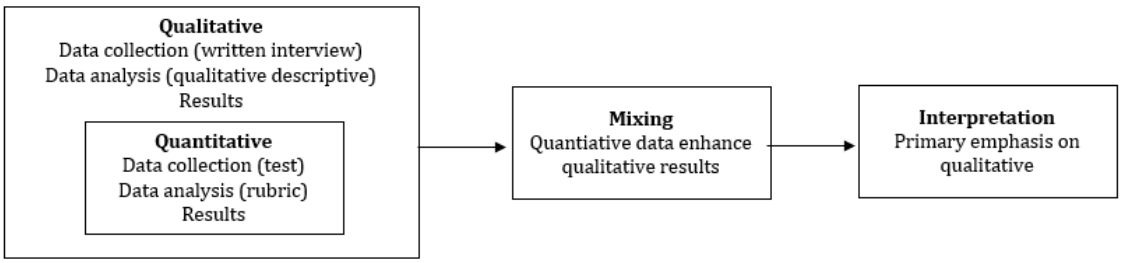


Figure 1. Embedded Design Mixed Method Research (Creswell, 2017)

The research steps are adjusted to the research design, as seen in Figure 1. After the research subjects and instruments have been designed, the first step is to conduct quantitative research. Data in quantitative research were collected using test questions. The second step is

to analyze the test result data. The third step is to interpret the test results using the categories. The fourth step is to conduct qualitative research by collecting qualitative data from written interviews embedded in the quantitative data test questions. The fifth step is to analyze qualitative data using qualitative descriptive techniques. The sixth step is to combine the analysis results of the two research types. The last step is to interpret the data where the quantitative data strengthens and deepens the qualitative data description.

RESULTS AND DISCUSSION

Results

Results of Decomposition Foundation

Decomposition becomes the CT foundation (minimum) used as the basis for the thought process in solving question 1. Decomposition is breaking down or grouping each absolute term based on the definition of absolute value (breaking complex problems into three absolute terms). It would be impossible for someone to solve question 1 without decomposing as the foundation. Question 1 can be seen in Figure 2, and the test results can be seen in Table 1.

His teacher asks a student about the set of absolute value equation solutions as follows!
Determine the set of solutions (HP) to the equation $|3x-2|-|x-3|=4-|x-2|$.
Then, the student solves the problem in the following way:

a. Group each absolute term based on the absolute value definition
b. Create a number line that fits the definition
c. Determine the set of solutions that satisfy the equation

The question: *The student completes the problem as discussed above. What CT foundation is applied by the student to the problem above? Explain why!*

Figure 2. Question 1 (Decomposition Foundation)

Table 1. Results of Decomposition Foundation

Criteria	Indicator	Frequency	Percentage (%)
An answer	Correct answer without valid reasons	27	96.43
	Wrong answer	1	3.57
	Correct answer with valid reasons	26	92.86
No answer	No answer	0	0

The correct answer to question 1 is "Decomposition". Based on the test results, it was found that 27 (96.43%) persons answered the question correctly, and 1 (3.57%) person answered wrong. Of the 27 persons correctly, only 26 (92.86%) persons could give valid reasons for their answers. Pre-service teachers give decomposition answers: "There is a thinking process in breaking down or simplifying the problem by grouping the problem into several absolute terms and then defining each of these absolute term values". One person gave the wrong reason: "Solving the problem based on the decomposition foundation because it simplifies the problem by making what is known in the problem". This reason is considered inappropriate because it makes what is known in the problem, not a thought process (CT foundation), in deciphering the problem simpler so that it is easy to solve. Based on the percentage of correct answers accompanied by valid reasons, the "decomposition" thinking foundation is categorized as "very high". It can be concluded that 21st-century professional teacher candidates already understand how to solve problems by simplifying problems (decomposition) which is "very good or high", where they can break down, sort, or divide complex problems into smaller sub-parts of more specific problems.

Results of Pattern Recognition Foundation

Pattern recognition becomes the CT foundation (minimum) used as the basis for the thought process in solving question 2. Pattern recognition is a thought process of finding or using the definition of absolute value according to the pattern of completion studied in the previous problem to determine the value of each absolute term in the problem to be solved. It would be impossible for someone to solve question 2 without pattern recognition as the foundation. Question 2 can be seen in Figure 3, and the test results can be seen in Table 2.

A student is given an absolute value equation problem below.
Determine the set of solutions (HP) to the equation $|2x - 3| = |-x|$.
Then he worked on the problem in 2 ways: by definition and by squaring the two sides. It was concluded that the two methods were more effective, efficient, and optimal. When the student is given a similar problem, the student works in 2 ways, as above. What CT foundation does the student apply to this problem? *Explain why!*

Figure 3. Question 2 (Pattern Recognition Foundation)

Table 2. Results of Pattern Recognition Foundation

Criteria	Indicator	Frequency	Percentage (%)
An answer	Correct answer without valid reasons	0	0
	Wrong answer	5	17.86
	Correct answer with valid reasons	23	82.14
No answer	No answer	0	0

The correct answer to question 2 is "Pattern Recognition". Even though question 2 only measures basic theoretical knowledge or understanding, it can still measure computational thinking skills based on pattern recognition. Based on the test results, it was found that 23 (82.14%) persons answered the question correctly with valid reasons, and 5 (17.86%) persons answered wrong. They answered based on "pattern recognition" because "In question 2, there is a thought process in identifying problem-solving patterns with relevant or similar previous problem patterns so that the questions are done the same way. There was already a keyword in the explanation of question 2, namely similar problem". Based on the percentage of correct answers accompanied by valid reasons, the "pattern recognition" thinking foundation is categorized as "very high". It can be concluded that the ability to recognize patterns in questions is categorized as "very good or high". It means that, in general, 21st-century professional teacher candidates already understand how to solve problems by observing or analyzing, looking for patterns in the questions to be solved or modifying patterns from previous questions and applying them to new questions. Even though question 2 only measures basic theoretical knowledge or understanding, it can still measure computational thinking skills based on pattern recognition.

Results of Algorithms Foundation

Algorithms become the CT foundation (minimum) used as the basis for the thought process in solving question 3. The algorithm in this problem calculates the fastest meeting time of 2 friends by making a sequence of steps for the route taken. There are three models of correct answers from pre-service teachers regarding solving question 3. The three models of answers can be seen in Figures 5, 6, and 7. Each answer correctly answers that the fastest time for two persons to meet is 4 minutes even though the route is different.

The two friends must quickly meet on a tile on the following map. They can move horizontally or vertically to their neighboring tiles within 1 minute. If they reach a tile with a bike or car, they can move faster, two tiles in 1 minute by bicycle, or five tiles in 1 minute by car. They cannot enter tiles that were flooded. Here is a map of their encounter.

Figure 4. Question 3 (Algorithms Foundation)

Table 3. Results of Algorithms Foundation

Criteria	Indicator	Frequency	Percentage (%)
An answer	Correct answer without valid reasons	1	3.57
	Wrong answer	0	0
	Correct answer with valid reasons	27	96.43
No answer	No answer	0	0

Based on Table 3, it was found that 27 (96.43%) persons answered the question correctly with valid reasons, and 1 (3.57%) person answered correctly without valid reasons. The "algorithms " thinking foundation is categorized as "very high". It can be concluded that the ability of 21st-century professional teacher candidates is "very good or high" in understanding how to solve problems by describing logical and systematic steps.

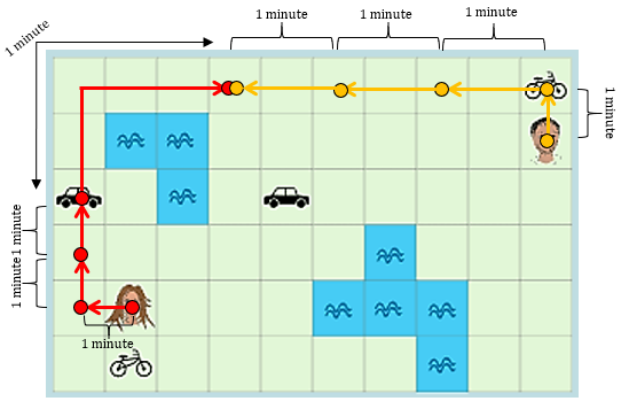


Figure 5. Answer Form Based on Algorithms Foundation (Model I)

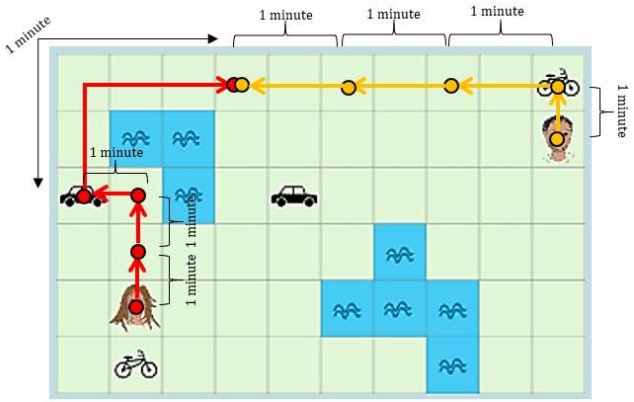


Figure 6. Answer Form Based on Algorithms Foundation (Model II)

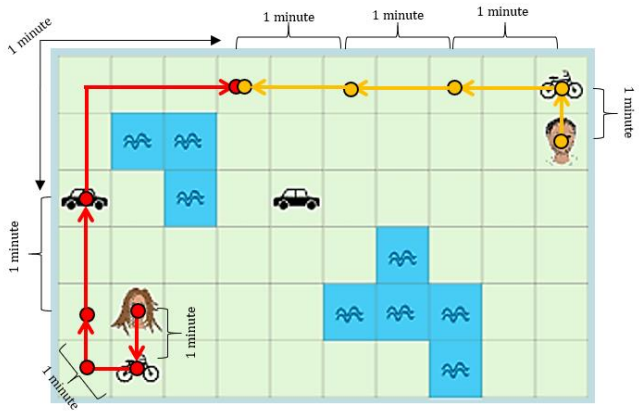


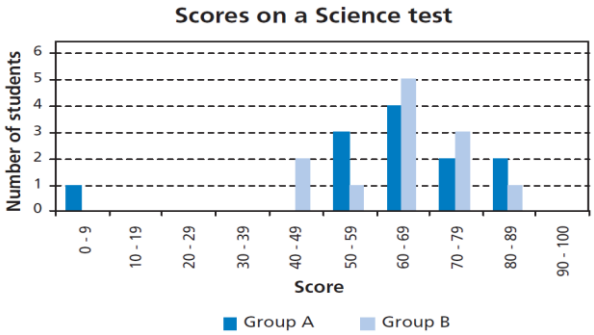
Figure 7. Answer Form Based on Algorithms Foundation (Model III)

Correct answers are divided into 3 model answers which can be seen in Figure 5 as Model I, Figure 6 as Model II, and Figure 7 as Model III. Fourteen (50%) persons made a travel route model like Figure 5, and 11 (39%) persons made one like Figure 6. These two travel routes are the same; that is, a girlfriend walks for 3 minutes to the car and continues the journey by car for 1 minute. At the same time, the male friend walks for 1 minute to the bicycle and continues to ride the bicycle for 3 minutes. What distinguishes the travel route in the two pictures is only the walking route taken by the female friend to the car's position. Both friends still need the fastest time of 4 minutes to meet on the same plot even though the travel route is slightly different. There are 2 (7%) persons who made a travel route model like Figure 7. This route is different from the two previous routes. On this route, the girlfriend walks for 1 minute to the bicycle, then rides for 2 minutes to the car, and continues the journey by car for 1 minute. At the same time, the male best friend walks for 1 minute to the bicycle and continues for 3 minutes. The two friends met on the same plot in 4 minutes. The description of logical and systematic steps in determining the fastest travel route for these two friends to meet can be referred to as an "algorithmic" thinking process.

Results of Abstraction Foundation

Abstraction becomes the CT foundation (minimum) used as the basis for the thought process in solving question 4. Abstraction is marked by the existence of a thought process in making a mathematical model of the values of the two groups in the form of a frequency distribution table. Mathematical models are made based on the information (which is known and asked) in the problem. Only important and relevant problem-solving information is used to create a mathematical model. Answers from pre-service teachers can be seen in Figure 8.

The diagram below shows the science test scores of two groups of students (Group A and Group B). The average value obtained by Group A is 62, and the average obtained by Group B is 64,5. Students are declared to have passed the exam if they score 50 or more.



Regarding the diagram above, the teacher teaching Groups A and B stated that Group B got better results than Group A on this exam. Students in Group A disagreed with the teacher's statement. Students in Group A convinced their teacher that Group B was no better than them. Give arguments based on available graphs that can support Group A's statement! Explain what CT concepts you use in solving this problem! *Explain why!*

Figure 8. Question 4 (Abstraction Foundation)

Table 4. Results of Abstraction Foundation

Criteria	Indicator	Frequency	Percentage (%)
An answer	Correct answer without valid reasons	6	21.43
	Wrong answer	1	3.57
	Correct answer with valid reasons	21	75
No answer	No answer	0	0

Based on the test results, 27 (96.43%) persons answered correctly, and 1 person (3.57%) answered incorrectly. Of the 27 persons, there were 21 (75%) persons who could give good reasons for their answers. Based on the percentage of correct answers accompanied by valid reasons, the "abstraction" thinking foundation is categorized as " high". It can be said that the abstraction ability of 21st-century professional teacher candidates is categorized as "high". It means pre-service teachers can make a mathematical model based on the information in the problem, making it easier to find solutions or answers. Twenty-one (75%) persons stated, "Group A is better than Group B because the number of students who passed in Group A was 11 persons and in Group B there were 10". It is why "Group A is better than Group B".

Abstraction

Value intervals	Number of Group A	Number of Group B
0-9	1	0
40-49	0	2
50-59	**3**	**1**
60-69	**4**	**5**
70-79	**2**	**3**
80-89	**2**	**1**
Total	12	12
Passes	3+4+2+2=11	1+5+3+1=10

Figure 9. Answer Form Based on Abstraction Foundation

One form of the correct answer can be seen in Figure 9. This correct answer was obtained based on a mathematical model in the form of a frequency distribution table from groups A and B, resulting from important and relevant information from question 4. Information that is not useful for solving the problem is not used. It is known as the process of abstracting the problem. There was 1 (3.57%) person stated that "Group B is better than Group A". This statement is true, but not following what was asked in question 4. Question 4 requires us to look for reasons that support the statement that "Group A is better than Group B". One person answered incorrectly on question 4. It proves that accuracy is needed to understand the information about the problem. Not all of the information in the question is used in answering the question. Only relevant information is used. Six persons answered correctly but did not explain where the answers were obtained.

Discussion

Based on the study's results, in general, the Computational Thinking (CT) ability of 21st-century professional teacher candidates has shown a good level of CT ability (high category). A person is said to have good Computational Thinking skills if he can apply the CT foundation or thought process in solving problems (Anistyasari et al., 2020; Fauji et al., 2022). Applying the CT foundation to every problem to find a solution to a problem is a benchmark for computational thinking (Aziz, 2022; Fitriani et al., 2021). It is in line with the results of previous research, which said that the foundation of CT is the central thinking concept in solving problems using Computational Thinking abilities (Astuti et al., 2023). In addition, CT foundations are also called CT skills indicators which can be used as structured steps to find solutions (Angraini et al., 2022). It shows that by knowing and being able to apply the basics of CT to a problem, a person can think computationally in solving problems.

The results showed that in question 1, which measures knowledge about the minimum foundation of "decomposition", 26 (92.86%) persons answered question 1 correctly. Break down or simplify the problem by grouping the problem into several absolute terms and then defining each of these absolute term values. This reason appropriates the concept of decomposition, namely solving complex problems into smaller parts by grouping them to be easier to understand and solve (Angeli et al., 2016; Powers et al., 2020; Dong et al., 2023). In decomposition, one can identify known and asked information from the problems given (Lestari & Roesdiana, 2023). Based on the relevant research results, decomposition is also closely related to the thought process of understanding problems in problem-solving skills. CT is also considered a further development or the latest innovation of problem-solving abilities because CT is a thought process that makes it easier for someone to make problem-solving decisions (Julianti et al., 2022).

Pattern recognition is the foundation of CT to determine similar or different patterns, which are then used to find solutions to problems. Question 2 measures knowledge about CT with a minimum foundation of "pattern recognition". There were 23 (82.14%) persons who answered question 2 correctly because the solution to the problem was obtained from a similar pattern of solving the previous questions, so the problem was solved in the same way or pattern. This reason appropriates the concept of pattern recognition, namely looking for similarities between various problems to be solved (Apriani et al., 2021). In solving problems using pattern recognition foundations, one can use generalizations of existing patterns to solve new problems (Angeli et al., 2016). Problem solutions will be easier to find if someone can recognize patterns in these problems (Angraini et al., 2022; Julianti et al., 2022; Rahayu et al., 2023).

The CT foundation used in filtering important information that can be used in problem-solving is known as abstraction. Question 3 examines how pre-service teachers use the

foundation of algorithms to solve problems. There were 27 (96.43%) persons who answered the question correctly. From the study results, three models of travel routes were obtained that could be made by the professional teacher. Based on the routes made, calculations are carried out according to systematic and logical steps. These logical and systematic steps are called algorithmic thinking processes, one of the foundations of CT thinking (Apriani et al., 2021; Supiarmo et al., 2021; Astuti et al., 2023). The algorithm is a step that helps to find answers to the problems given (Cahdriyana & Richardo, 2020; Chahyadi et al., 2021).

Question 4 measures the foundations of "abstraction". There were 21 (75%) persons who answered correctly. The questions are in the form of bar charts which contain various kinds of information. In order to solve it effectively, efficiently and optimally, the teacher must be able to think about how to classify (decompose) the current information. This information is designed to be a simpler mathematical model (abstraction) (Lestari & Roesdiana, 2023; Rahayu et al., 2023). Relevant research results show that someone who can abstract the problem will focus on essential data or information in the problem by making a mathematical model (Kamil et al., 2021; Rahayu et al., 2022). Based on abstract thinking, one examines or eliminates unnecessary (unimportant) information in mathematical problems to produce a problem-solving design or called a mathematical model (Supiarmo et al., 2021).

Each of these CT foundations has a relationship with one another. It can be seen from the results that have been described that when one of the questions requires at least one CT foundation to be used to find a solution to the problem, indirectly, the minimal foundation used also indicates other CT foundations. When doing decomposition, there are skills involved in pattern recognition, abstraction, and algorithms. It is proven that to solve problems with Computational Thinking, you must use a minimum of the existing foundation on Computational Thinking ability. Using at least one foundation in CT will involve other foundations in solving problems and finding solutions to problems (Rahayu & Ismawati, 2022). Question 3, measures the foundation of algorithms. The algorithm is used after there is a process of modelling the problem (abstraction). It can be assumed that in the process of "algorithm" in parallel, there is also a process of "abstraction". Similar to question 4, it can be seen that in the process of "abstraction", there is also a process of "decomposition" of the problem. In other words, we can assume that the four foundations of CT are not always separate from each other but also overlap (Budiarti et al., 2022).

The limitation of this research is that the research sample was only conducted in one class with a total sample of 28 students, and the sampling method was not carried out by random sampling. It is suggested that future researchers develop this research on a larger sample using random sampling to make the research results more accurate and representative. In addition, it is also recommended to conduct quasi-experimental research that compares the computational thinking abilities of the experimental and control classes. Another limitation is that the test instruments in this study did not focus on the same material or basic competency, so representative conclusions cannot be drawn about the teacher's CT ability in that material. The next research should focus on the same basic competency to conclude how computational thinking is in this material.

CONCLUSION

Based on the research results, the Computational Thinking (CT) skills of the pre-service teacher's mathematics in the Professional Teacher Education (PTE) program at Padang State University as prospective 21st-century professional teachers are generally categorized as “high”. Computational thinking focuses on four foundations: decomposition, pattern recognition, abstraction, and algorithms. Regarding knowledge of the 4 CT foundations, the prospective teacher's knowledge of the four principles of the CT foundation is categorized as

very good. In terms of understanding of solving math problems, it was concluded that, in general, teacher candidates were very skilled at using the 4 CT foundations in solving math problems. The data is strengthened by written interviews embedded in the test questions. From the interviews, it can be ascertained whether the teacher's answers follow the reasons. It was concluded that prospective teachers already have 21st-century professional teaching skills, namely Computational Thinking.

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