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Computational Thinking Processes in Solving the Corona Epidemic Model: Pre-service Maths Teachers

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Abstract: In the 21st century, pre-service mathematics teachers are expected to have problem-solving skills that are effective, efficient, and solutive and are in line with the mindset of computer experts. In learning mathematics, the concept of computational thinking (CT) is also needed and at this time, many still have difficulty solving mathematical problems in general, especially in solving problems in epidemic mathematical models. The subjects of this study were twenty-seven pre-service mathematics teacher students who took mathematical modeling courses. The researcher used the purposive sampling technique to select two research samples. The research method used was a descriptive qualitative research method in exploring the thinking process of pre-service mathematics teacher students in solving the problem of modeling the epidemic spread of disease. The results showed that the thinking process of the first subject began with identifying the problem and existing information by writing down the data in the form of a graph so as to get a certain pattern, which was then used as the basis for the process of transforming the problem into mathematical language. By adding assumptions related to the existence of environmental limitations in the next epidemic model, the concept of differential equations, in which there are integral properties and natural logarithms, can be used to find the solution to the epidemic model. The second subject was unable to solve the integral at hand. The researcher discovered that pre-service mathematics teacher students who correctly solved the problem in the mathematical model used CT components, namely decomposition, abstraction, pattern recognition, algorithm and mathematical literacy.

Introduction

The development of technology today has an impact on various fields, one of which is education, so the learning process is always associated with technology, which has an impact on the development of students' mindsets, namely computational thinking (CT) (Wing, 2010). Many countries have integrated computational thinking skills into their curricula, including Spain, Lithuania, Malaysia and Indonesia (Kamha, 2023; Mandanici, 2023; Sekhar, 2024). This CT integration process can be realized when teachers and prospective teachers are able to integrate and develop CT in classroom learning through its components.

According to Hachmann (2022) CT is an explicit command or instruction to solve problems. CT requires the process of decomposing a complex problem into simpler and more detailed problems, which is hereinafter referred to as decomposition (Beliën, 2007; Esteve-Mon, 2020; Klerides, 2010; Nordby et al., 2022; Villa-Ochoa, 2022). Furthermore, Curzon et al. (2014) define decomposition as the process of breaking down a problem into smaller parts so that it can help in solving the problem. Decomposition is one of the basic skills in solving problems (Marom, Waluya et al., 2023). In Selby (2015) findings, it is mentioned that decomposition is a CT skill that is difficult to master due to a lack of understanding of the problem to be solved and not fully understood. Many students seem to understand the concept of decomposition but have difficulty applying it in CT. In Rich (2020) research, he stated that decomposition ability is needed beforehand because it is the foundation of CT skills. Decomposition is

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an activity that allows us to gather important information in problem-solving.

The next component of CT is finding patterns; according to Yasin (2023), pattern recognition in CT is the ability to recognize similarities and differences in patterns or data trends that will be able to make predictions. At this stage, patterns or regularities are found in complex problems by looking at patterns in smaller problems (Liu, 2021). Pattern recognition is an important step that can help in finding solutions because, at this stage, there is an effort to understand the related data or information (Dubey, 2024; Palts, 2019). So, in CT, decomposition and pattern recognition simplify complex problems into smaller parts.

Furthermore, in the CT process, the role of finding ways to work with the parts that have been formed effectively, efficiently, and accurately is an abstraction. This CT component has been proposed by several researchers (Ezeamuzie, 2023; Rijke, 2018). Abstraction is an activity that allows us to realize various similarities between experiences that have occurred. According to Qian (2023), the abstraction process occurs by realizing the existence of similarities so that other characteristics or properties that are not needed are eliminated. According to Rose (2019), the abstraction process can be done by linking previous experiences with new experiences; the closer the relationship between old experiences and new experiences, the easier the abstraction process. Furthermore, Bjerke & Solomon (2020) describe abstraction as a vertical thinking process from previously built mathematical concepts into new mathematical structures. The main abstraction process is to classify the same properties of real conditions (Çakiroğlu, 2022). Abstraction thinking for students is an important thing to teach mathematical concepts in real-life contexts, especially mathematical models because students are expected to be able to make concrete mathematical models that come from things that are abstractions (in the imagination of students' minds) (Kaur, 2023).

Kirçali's research (2023) states that CT skills are algorithmic thinking built on principles from computer science as a structural, systematic, and metaphorical framework. It can be described as an instruction procedure for each step in finding solutions to problems (not only in computer science but in a broader context) (Oliveira, 2021). In line with the thoughts of Korkmaz (2019), who describes CT as explicit instructions in solving problems.

Next is the mathematical literacy process that will help solve problems in each step of the algorithm thinking using mathematical concepts (Marom Waluya et al., 2023). This mathematical literacy process not only gets a mathematical solution but translates the mathematical solution into everyday language and can be used as a solution needed to make decisions (Shute et al., 2017).

Many previous studies have examined the learning process integrated with CT by using various approaches to solving problems. Researchers have proposed problem-solving approaches in the computer field using CT (So, 2020a; Solairaja, 2023). This is different from Wing (2015) opinion, which states that CT skills are basic skills that must be learned and possessed by everyone in various fields of science. The rapid development of technology and computing requires CT to be integrated into all fields (Pei, 2018). Since CT is a thinking skill, it should be taught to students of all disciplines from an early age (Yadav, 2023).

In the research of T. Y. Lee (2014), a research study at the elementary school level through an unplugged process (social game play) which starts with solving puzzles using paper and continues on the game board and finally completes the solution on the computer. The results showed that this particular approach can help students better articulate algorithmic thinking patterns. The results of research from Borkulo (2021), which examines the use of conditional questions and the use of GeoGebra in the integration of CT in the mathematics learning process. Likewise, in research conducted by Curzon et al. (2014) with the research subjects being students, the study's results were related to CT's ability to solve problems with the help of ICT. This research produced five main components of CT, namely abstraction ability, decomposition ability, algorithm, evaluation, and generalization. Several studies have presented that CT can be used in solving problems in the learning process and is able to construct students' cognitive and practical activities. All the studies mentioned the research subjects are students, and no one has reported research on prospective teachers, who are the most important asset that will provide and develop the learning process for students.

Our initial observations found that prospective mathematics teachers still have difficulty finding solutions to mathematical modeling problems. They tend to still look at existing examples of modeling cases. In addition, when given case explorations related to mathematical modeling problems, they have difficulty in modeling (constructing problems into appropriate mathematical language) and solving mathematical concepts formed from the modeling process (Araya, 2021). Based on previous research related to the learning process to find solutions to problems, the researchers revealed that CT is an effective, efficient, and solutive approach to finding solutions to problems in the learning process (Kallia, 2021; Maharani, 2021; Sırakaya, 2020; Zhang and Nouri, 2019).

Based on what has been explained, CT ability is needed to find solutions to problems based on theoretical and previous studies. So, the researcher will reveal the components of CT formed from the analysis of prospective mathematics teachers' thinking processes in finding solutions to mathematical modeling problems. This research is expected to produce new CT findings that will help the teaching process.

Materials and Methods

Research Design

This study will use a qualitative approach to describe the thinking process of prospective teachers in finding solutions to mathematical modeling problems (Alqahtani, 2023). In his book, Djamba & Neuman (2002) state that qualitative research has the characteristics of natural settings, researchers are the key research instruments, multiple data sources, inductive data analysis, emerging designs, and holistic reports.

Sample

The research data were taken from fifth-semester mathematics teacher candidate students. The subjects of this study consisted of twenty-six students, consisting of nine male students and seventeen female students aged between 20 and 22 years. The research subjects were selected using the purposive sampling technique. In his book, Sukestiyarno (2018) states that the purposive sampling technique is a sample selection technique as a data source that uses certain considerations. In this study, research subjects were selected with the first criterion being the final result by answering correctly and incorrectly; the second criterion is students who have active communication with the aim of facilitating the extraction of information in the study; the third criterion is students with female gender and 21 years old. According to Santrock (2011), the criteria were chosen because cognitively, individuals with these criteria have begun to think interpretatively. Furthermore, research subjects who answered correctly were given the code T1, and subjects who answered incorrectly were given the code T2. Data collection techniques in this study were interviews and activity notes using mathematical modeling problems. Qualitative data analysis was carried out by reducing existing data, presenting data, interpreting data, and drawing conclusions based on the data obtained.

The mathematical modeling instrument will be validated by expert judgment. The research instrument was designed in accordance with the research objectives, and then a limited trial of the existing research instrument was carried out. The results of the item validity test showed that the three mathematical modeling questions were valid and reliable. In addition, conducting interviews will refer to expert-validated interview guidelines in digging up structured and in-depth information.

Collection of Data

When working on test questions and interviews, data is obtained from written test results. To clarify the test questions that have been used, an in-depth interview will be used (Mukherjee, 2022). The research instrument is a test question that will be used to collect test data by giving mathematical modeling questions. The research instrument is a test question to collect data about the thinking process in solving problems.

"At 2022 in Indonesia there was a coronavirus epidemic for a period of 15 months, there were 8 people died. Using the data below, how can equilibrium conditions occur from the Corona epidemic equilibrium model?"

Table 1. Table of the number of individuals infected with Corona.

Month (t)	Number of Infected (P)	Month (t)	Number of Infected (P)
0	1	8	20
1	2	9	23
2	2	10	25
3	3	11	29
4	5	12	32
5	7	13	34
6	10	14	38
7	14	15	44

Data Analysis

In this study, triangulation of data sources will be carried out to maintain validity and reliability by comparing the answers to the mathematical modeling questions of the epidemic with the results of in-depth interviews to extract information from respondents. The CT process will be analyzed using APOS Theory (Action, Process, Object, and Scheme) to explore the computational thinking process (Oi-Lam & Zhihao, 2021). This APOS theory approach can explain the development of each individual's schema in mathematical modeling (Wolfengagen, 2021).

The initial stage in analyzing data in this study was by transferring data to solve mathematical modeling problems; the next step was data reduction, performing the abstraction process, compiling data in each part, and grouping CT component data. After that, coding was carried out and ended with drawing conclusions. In the coding process, the researcher divides the data into three columns, namely, column one, which contains raw data. In the second column, the codes will be written per sentence on the raw data, and the third column contains the code for all data segments obtained. The following will provide an explanation of the use of the final code, as shown in Table 2.

Table 2 . Stages Of Coding On Apos In The Ct Process.

CODE	Descriptions		Code	Descriptions
	Differential Equation			Processes
	Mathematical modelling			Object
	Integral			Schema
	Natural Logarithm		*Inter-Action*	Interiorization Action
	Mathematic Solution		*Mathematical Literacy*	Mathematical Literacy
	Possible solution		*Enca-Pro*	Encapsulation Processes
	Equilibrium Mathematical modelling			Logistic Function
	Action		*De-Enc*	De Encapsulation

step after finding a model in the form of a differential equation is to group the variables in the equation. The next step in determining the model is to integrate the two segments. In the integral process, good mathematical literacy skills are needed, which are related to finding the solution of the equation with the help of the concepts of natural logarithm and absolute value until finding the solution of the differential equation. The subject looked for a special solution and continued to look for a general solution. The last step is to describe the general solution, which is still a mathematical symbol, in everyday language.

Result

This study found that the CT process at T1 began with decomposing problems and information, determining data patterns, thinking abstraction, algorithmic thinking, and thinking mathematical literacy in solving and translating mathematical solutions into real-life solutions. Furthermore, the second finding on T2 performs the CT process, starting with decomposition, pattern recognition, and abstraction. In the process of thinking, algorithms and mathematical literacy appeared to be obstacles. T2 got interference when doing the algorithm process, namely related to the use of the Taylor series algorithm and the lack of mathematical literacy related to the algorithm.

Before finding the solution to the problem, the subject first decomposes the problem so as to obtain important data and information. Based on the existing data, it is then described in a diagram and gets a certain pattern. Namely, the data moves exponentially. Based on the data and information obtained, it is converted into mathematical language and obtained a differential equation. The first

In this study, participants were fifth-semester mathematics teacher trainees (9 males and 17 females) who were taking a mathematical modeling course. They were given a written test related to CT in mathematical modeling. The test results showed 6 high scores (all female) and 20 medium scores (9 male and 11 female). In the study, two samples will be selected: one person from the high-score group as the first sample, symbolized by T1, and one from the medium-score group, symbolized by T2. The category in the selection of samples is female prospective teacher students, with the consideration that one of them is that there is no male who has the highest score, can communicate actively, and is 21 years old.

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Permasalahan : Kondisi keseimbangan dari Model Epidemi !

1. Mencari Model Epidemi
2. Mencari Keseimbangan dari Model Epidemi

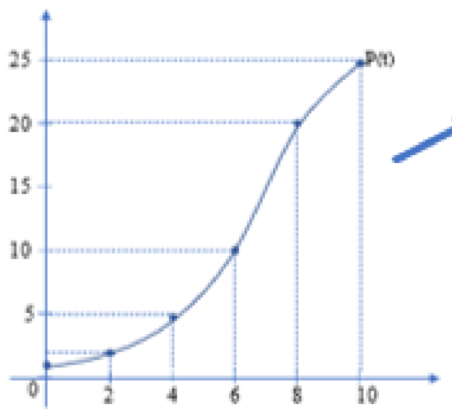
Translation :

Problem:

The equilibrium condition of the epidemic model!

1. Finding the epidemic model
2. Finding the equilibrium of the model

Figure 1. Decomposition Thinking by T1.



Berdasarkan dari grafik data yang bergerak secara eksponensial maka data didekati dengan fungsi logistic dengan model SI

Translation :

Problem based on the graph the data moves exponentially so it can be approximated by a logistic function with the SI (Susceptible and Infections) model:

$$\frac{dP(t)}{dt} = \alpha P(t)R(t)$$

$P(t)$ is the population size,

$R(t)$ is the number of infected individuals

α is the disease transmission rate

Figure 2. Pattern Recognition Process by T1.

Next, we will describe the CT process in finding the solution of the mathematical model of the selected participants.

Data Analysis of Highest Score (T1)

At this stage, the researcher analyzed T1's answer sheet, which was complemented by field notes and interview results. T1 generally had almost the same score as the other subjects. In this study, we analyzed the action stage in APOS theory. In the first stage of action, T1 understood the problem by describing what was known and what was the problem to be solved. The activities carried out by T1 break the problem into two parts: first, finding the Corona epidemic model and second, finding the equilibrium point of the epidemic model. T1 decomposes the problem and finds a solution (Khan, 2024; Kuo, 2020; So, 2020b).

$$\frac{dP(t)}{dt} = \alpha P(t)R(t)$$ $P(t)$: Banyaknya Populasi $R(t)$: Banyaknya individu yang terinveksi α : Angka penularan penyakit	Translation : $$\frac{dP(t)}{dt} = \alpha P(t)R(t)$$ $P(t)$ is the population size, $R(t)$ is the number of infected individuals α is the disease transmission rate

Figure 3. Abstraction Process by T1.

$$\frac{dP(t)}{dt} = R_0\, P(t) \left(\frac{K-P(t)}{K}\right)$$
$$\Leftrightarrow \int \frac{dP(t)}{dt} = \int R_0\, P(t) \left(\frac{K-P(t)}{K}\right)$$
$$\Leftrightarrow \int \frac{dP(t)}{R_0\, P(t)\left(\frac{K-P(t)}{K}\right)} = \int dt$$
$$\Leftrightarrow \int \frac{dP(t)}{R_0\, P(t)\left(\frac{K-P(t)}{K}\right)} = \int dt$$
$$\Leftrightarrow \frac{1}{R_0}\int \frac{1}{P(t)} dt + \int \frac{\frac{R_0}{K}}{R_0 - \frac{R_0}{K}P(t)} dP(t) = \int dt$$
$$\Leftrightarrow \int \frac{1}{P(t)} dt + \int \frac{\frac{R_0}{K}}{R_0 - \frac{R_0}{K}P(t)} dP(t) = \int R_0\, dt$$
$$\Leftrightarrow ln|P(t)| = ln\left|\frac{\frac{R_0}{K}}{R_0 - \frac{R_0}{K}P(t)}\right| = R_0 + c$$

The Partial Integral Algorithm

Translation :

By using the partial integral algorithm, we obtained :

$$ln|P(t)| + ln\left|\frac{\frac{R_0}{K}}{R_0 - \frac{R_0}{K}\big(P(t)\big)}\right| = R_0 t + c$$

Figure 4. Algorithm Thinking by T1.

Furthermore, at this stage, T1 made a data simulation by describing the data into a graph, and an exponential data growth pattern was seen so that the data would be approached using a logistic model with the SI (Susceptible Infection) model. T1 connected data and information with concepts to find further solutions. By reading, understanding the data, and being explored into thoughts that are poured into the concept of differential equations. This can be seen in the following Figure 2.

In this action stage, T1 understands the problem that has been found from the results of decomposition and pattern recognition by describing it in mathematical language. T1 represented the variables involved in the problem in mathematical language in the form of differential equations by assuming $P(t)$ is the number of populations, $R(t)$ is the number of infected populations, and α is the transmission rate. In this process, T1 reflects abstraction thinking activities that come from unstructured abstractions to abstracts that will be developed (Simon, 2020).

The action stage is carried out by T1 by making links between data, information, and problems with the concept of logistic modeling so that a new understanding is formed to find a solution. By reading, understanding T1 processes in his brain so that it is explored and poured into the concept of linear differential equations as in the following Figure 4.

Furthermore, Subject T1, at this stage, after using the concept of partial integral stops, T1 tried to do mathematics by digging up information related to the properties of natural logarithms to get the solution of the modeling. The next problem after finding the model is how to determine the balance of the model. By adopting the concept of an equilibrium point, the equilibrium condition of the model is obtained when the change in the population of infected individuals is zero. Using the mathematical literacy process, T1 solved the mathematical concepts well, arrived at a mathematical solution, and translated it into everyday language. Subject T1 has performed the mathematical literacy process, namely solving problems with mathematical concepts and translating mathematical solutions into everyday language (Genç, 2021). Look at the following Figure 5.

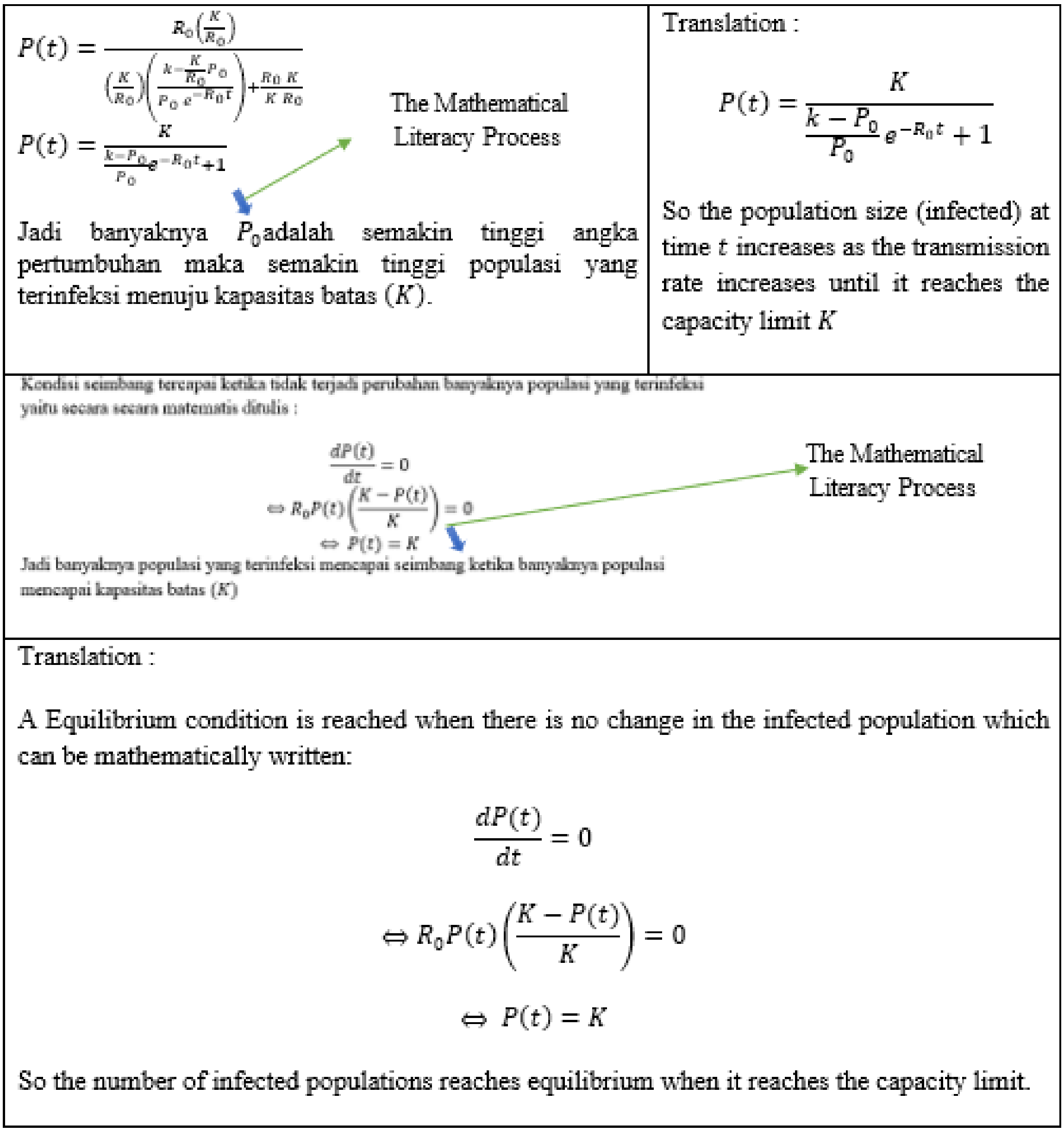


Figure 5. The Mathematical Literacy Process by T1.

Subject T1 is at the action stage by solving problems with the concept of differential equations, and there is an interiorization process at the action stage in the form of changing procedural activities to constructional activities that exist in his mind without doing all the stages. To find out more in-depth information related to subject T1, interview activities were carried out in the form of more in-depth information, so the following interview was conducted:

R : "What do you do after describing the problem into mathematical language?"

T1 : "Describe the variables in the problem with $P(t), R(t), \alpha,$ and then construct the differential equation:"

$$\frac{dP(t)}{dt} = \alpha P(t)R(t)$$

At this stage, T1's thinking process uses previous experience to become something new by describing differential equations. At this stage, T1's thinking involved the construction of new knowledge at a higher level.

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Then this thinking process is described as abstraction thinking (Cetin, 2017).

In APOS theory, the process is the second stage. In subject T1, the process stage is passed by developing a problem-solving plan with regular steps until getting the flow in carrying out the next steps, namely by using the algorithm in partial integrals, which is then supported by good mathematical literacy skills, namely being able to solve using the properties of natural logarithms and the concept of equilibrium points in the model. Subject T1 gets a mathematical solution, which is then translated into everyday language (Figure 4 and Figure 5).

Furthermore, researchers wanted to get information related to data well, so they continued the following interview :

R :"How did you get the mathematical solution?"

T1 : "Previously, I used the natural logarithm property to find the mathematical solution, and by using the concept of equilibrium point, I got the equilibrium solution of the model. After getting the mathematical solution, I translated the solution into everyday language".

From the results of the interview, T1 conducted a mathematical literacy process that can be seen as completing the integral process by using the properties of natural algorithms to find a mathematical solution. Furthermore, from the mathematical solution, T1 describes the mathematical solution into everyday language, which will later become the solution to the problem. From Figure 5 describes the third stage of APOS, namely, the object. At this stage, students' cognitive structure is seen where there is a transformation process carried out in one unit. This can be seen from the interview when providing steps in finding a mathematical solution and describing the solution to be the solution to the problem needed. This construction process occurs at this stage, which is reflected in the student's thought process when reflecting on the action applied by constructing the problem variables P, R, and α, which will later be applied to certain processes. Furthermore, based on existing data and information. This action is carried out repeatedly so that the encapsulation process occurs. T1 used the nature of natural logarithms in the partial integral algorithm so as to produce a mathematical solution.

The last stage in APOS theory is schema. At this stage, a construction is carried out that will connect actions, processes, and objects separately to certain objects in order to get certain schema results. This can be seen in the following picture.

The schema stage in the thinking process that occurs is related to the stages that have been carried out in solving the problem that is answered by finding the number of balanced populations when reaching the limit capacity $(P(t) = K)$. Schemes formed in a person's thinking can show knowledge that has been arranged in a pattern that has a connection and is built from various previous experiences so that it can be used to predict further new knowledge (Jiang, 2023). As a whole, it can be seen that T1 has carried out a computational thinking process, which can be seen from his way of thinking, namely by decomposing the problem into two, namely the problem of finding the mathematical model and finding the balance of the model. Furthermore, T1 also used data and information to find the growth pattern of the logistic model (pattern recognition) and continued by translating the pattern found into mathematical language to form a mathematical model in the form of a differential equation (abstraction). To find a mathematical solution, T1 used the concept of partial differential equations (algorithm) and the properties of natural logarithms. T1 found a mathematical solution to the model, which was finally translated into a problem

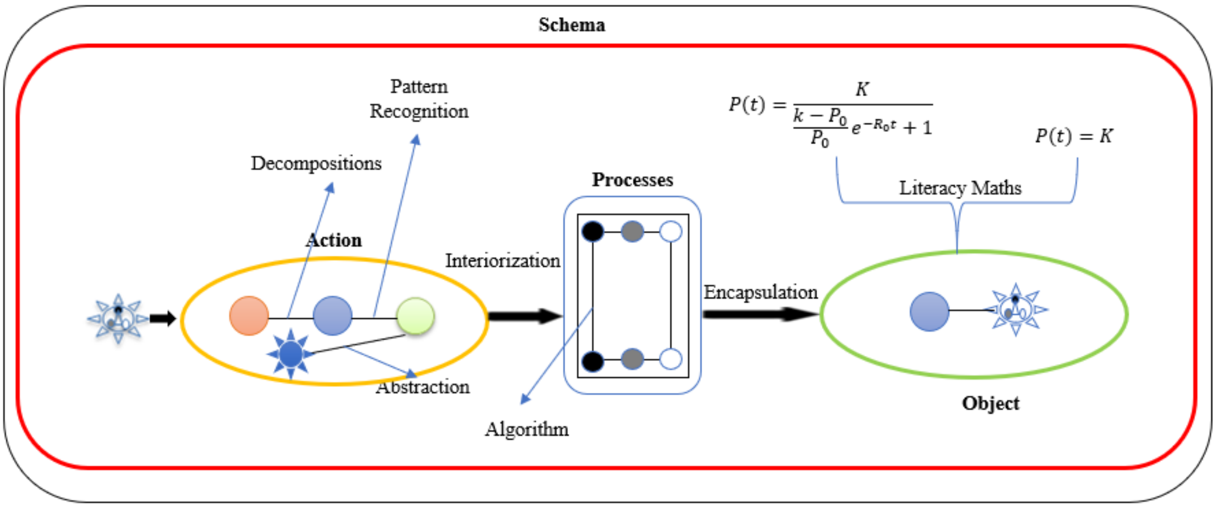

Figure 6. The Thinking Process Carried Out by T1.

solution in everyday language (Mathematical literacy). The stages of action, process, and object in order to create a good scheme can be seen in Figure 6.

In Figure 6, it is clear that the CT process in producing solutions to mathematical modeling starts with the thinking process of decomposition and pattern recognition, which produces a certain pattern that becomes the basis for the abstraction thinking process by translating the problem into mathematical language. Then, an algorithmic thinking process occurs iteratively using the partial integration concept algorithm. All processes went well. Stages in the object occur well, namely being able to find solutions to mathematical models and balance conditions by exploring mathematical literacy to find mathematical solutions in the form of models and balance solutions, which are then both described into solutions that have been described in everyday language.

Data Analysis of Moderate Score Group (T2)

Subject T2 described his thought process with CT in finding the solution to problems related to differential equations through his answer sheet. The first step T2 did was to find a solution related to the differential equation, namely partially integrating the existing differential equation to get the solution P(t). This can be seen in Figure 7 below:

The researcher conducted an interview with subject T2 to obtain in-depth information, namely:

R : “What do you do for this process?”

T2: “Before looking for the equilibrium condition of the model, I first determine the mathematical model by using the partial integral rule”.

T2, at this action stage, tries to make connections between concepts so as to form new understandings. T2 made the relationship in the concept into a thought process in finding the solution of a differential equation by using the partial integral algorithm to get a new understanding of the next process. The process stage is the second stage of the APOS concept. The algorithm process is very important because it involves many activities, such as mathematical literacy, to get the solution to the problem (Angeli, 2022). Furthermore, there is encapsulation in the partial integral algorithm process, and the scheme has an error when calling long-term memory. T2 did not do the backward process (calling the previous concept) in the partial integral algorithm, so it was unable to produce a new understanding (get the solution to the problem). Note Figure 8 below:

At the process stage, T2 looked for a mathematical model symbolized P(t) by solving the differential equation. On the T2 answer sheet, it can be seen that there is a process that should not occur, namely the use of the addition property on the concept of natural logarithm that is not correct, resulting in an incorrect solution. Furthermore, based on this, the researcher continued to

$$\Leftrightarrow \int \frac{1}{P(t)}\,dP(t) + \int \frac{\frac{R_0}{K}}{R_0 - \frac{R_0}{K}P(t)}\,dP(t) = \int R_0\,dt$$

$$\Leftrightarrow ln\big(P(t)\big) + ln\,\frac{R_0}{K}\frac{1}{R_0 - \frac{R_0}{K}P(t)} = R_0 t + c$$

$$\Leftrightarrow ln\left(P(t) + \frac{R_0}{K}\frac{1}{R_0 - \frac{R_0}{K}P(t)}\right) = R_0 t + c$$

$$\Leftrightarrow ln\left(P(t) + \frac{1}{K - P(t)}\right) = R_0 t + c$$

Algorithmic Process Disconnection

Figure 7. Algorithm Thinking by T2.

$$\Leftrightarrow ln\left(P(t) + \frac{R_0}{K}\frac{1}{R_0 - \frac{R_0}{K}P(t)}\right) = R_0 t + c$$

$$\Leftrightarrow ln\left(P(t) + \frac{1}{K - P(t)}\right) = R_0 t + c$$

$$\Leftrightarrow ln\left(\frac{P(t)}{K - P(t)}\right) = R_0 t + c$$

$$\Leftrightarrow ln\left(\frac{1}{\frac{K}{P(t)} - 1}\right) = R_0 t + c$$

$$\Leftrightarrow \left(\frac{1}{\frac{K}{P(t)} - 1}\right) = e^{R_0 t + c}$$

$$\Leftrightarrow 1 = e^{R_0 t + c}\left(\frac{K}{P(t)} - 1\right)$$

$$\Leftrightarrow 1 = e^{R_0 t + c}\frac{K}{P(t)} - e^{R_0 t + c}$$

$$\Leftrightarrow 1 + e^{R_0 t + c} = e^{R_0 t + c}\frac{K}{P(t)}$$

$$\Leftrightarrow P(t) = \frac{e^{R_0 t + c}K}{1 + e^{R_0 t + c}}$$

De-encapsulation Process

Figure 8. De-encapsulation by T2.

explore data and information using interviews to ensure the flow of the T2 thinking process.

R : "Do you see any mistakes in solving partial differential equations? Can you explain it?"

T2 : "After I checked again, it turns out that there was an error in this step, namely, I was wrong in using the addition property in natural logarithm".

Based on this explanation, the researcher found that there was a disconnected thinking process (Figure 8). In this process, T2 did not have a good flow of thinking from previous experience and the loss of long-term memory, or, in other words, the lack of mathematical literacy of T2. At the process stage, T2 was unable to produce a correct and perfect solution. The subject should understand the nature of natural logic in solving differential equations. The APOS stages in T2 were not able to run well.

In Figure 8, it can be seen that there was an error in the previous stage, so the scheme was not perfect in the final stage. This happened because of the disconnection of experience from the previous stage. In other words, T2 was not able to do mathematics literacy well. The thinking flow of T2 can be seen in the Figure below:

Discussion

Based on the research results obtained, prospective teachers' thought process in solving mathematical modeling problems uses the CT component. From the data obtained from the written test results and interviews in finding solutions to mathematical modeling, they use decomposition, pattern recognition, and abstraction abilities, which aligns with research (Bal, 2022; Hooshyar, 2021). In this study, these three components are then used to find patterns in mathematical modeling problems. Furthermore, the algorithmic process with good literacy skills is used to find solutions to existing problem patterns (Marom Waluya et al., 2023).

Decomposition occurs at the action stage, namely activities in the process of object transformation and instructions in the stage of finding solutions to mathematical modeling. Subjects in finding solutions to mathematical modeling by breaking down problems into simpler ones and collecting important information in the process of finding solutions. T1 did well and was able to transform the information in the mathematical modeling problem by making instructions for the stages in finding

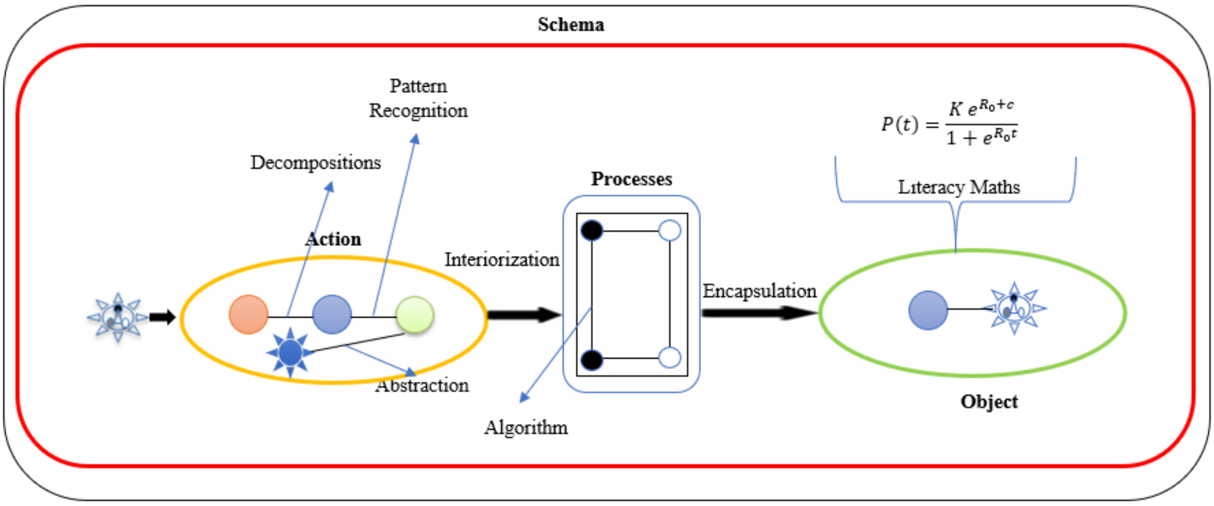

Figure 9. The Thinking Process Carried Out by T2.

Figure 9 describes T2 thinking flow using CT. Subject T2 found the thinking flow of decomposition, pattern recognition, and abstraction. The CT process was interrupted when performing the algorithm process, and subject T2 mathematical literacy skills were not good, so there was an error at the de-encapsulation stage so that no old knowledge was called in finding a solution to the problem, no new knowledge was found by T2. Subject T2 should have called on old knowledge related to the nature of addition to the natural logarithm in the partial integral algorithm. Based on this, T2 did not find the correct solution, so the final score was not perfect.

solutions to mathematical modeling, while T2 was also able to decompose the problem well. The next stage of action is related to the pattern recognition ability of subjects T1 and T2 in this study, which went well. Both subjects are able to find certain patterns, namely, based on data that grows exponentially, the epidemic problem of disease spread can be approached with a logistic model, namely the Susceptible and Infectious (SI) disease spread model (Marom, Harianto, et al., 2023).

Furthermore, in this study, subjects T1 and T2 also both showed the ability to generalize problems by translating problems into mathematical language based on the results of patterns and data formed so that it becomes a differential

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equation. This is in line with the results of previous research, namely that students' abstraction abilities have an important role in problem-solving, including mathematical modelling (Cetin, 2017; Simon, 2020).

The findings of this research provide information related to the construction of differential equations obtained from the process of decomposition, pattern recognition and abstraction of problems, and data on disease spread. Furthermore, the solution of the differential equation is able to be solved perfectly through a good algorithmic process and literacy skills. The cause of the error in finding the solution to the problem is due to the interrupted algorithmic process; the incorrect use of the natural logarithmic sum property indicates this. This happened because of the lack of mathematical literacy in building the algorithmic process. This is different from the research of Cutumisu (2019). The subjects in this study were prospective teacher students at the primary level. The previous study focused on analyzing students' work in solving learning problems with CT, including decomposition, pattern recognition, abstraction, and algorithms. The previous study informed us that the algorithm component performed by students was the lowest process. The cause of error is the lack of concept knowledge in the algorithm process.

The CT process intersects with mathematical modeling skills, which can be seen from the CT steps that previous researchers have proposed. The main model of CT is related to the description of the problem, solving the problem, and translating the solution of the problem properly (Shute et al., 2017; Tsarava et al., 2022). The stages of the mathematical modeling process are describing the problem variables, simplifying the problem by adding assumptions to the model, translating the problem into mathematical language, solving the problem with mathematical concepts, and translating the mathematical solution into a good problem solution (Biembengut and Hein, 2013).

The results of this study contribute to further research in the form of proposed components of computational thinking, namely the processes of decomposition, pattern recognition, abstraction, algorithms, and mathematical literacy. This component is slightly different from Bocconi et al (2018), who proposed abstraction, algorithm, decomposition, automation, and generalization as CT components. Based on the results of this study, CT components can be used to find solutions and as a reference in developing learning in the classroom, especially in mathematics learning. The injection of CT abilities in learning can be started by prospective teachers preparing themselves to explore students' CT abilities at school when teaching practice activities exist. This research is in line with previous research conducted by I. Lee (2020), which is related to the design and implementation of CT and STEM integration in the school curriculum (K–12). The results of this study show that most teachers and students have positive responses regarding the integration of CT in the school curriculum so that it can contribute to the professional development of teachers.

Conclusion

The results of this study's description, data analysis, and discussion provide recommendations for finding solutions to mathematical modeling that can use CT thinking components consisting of problem decomposition ability, pattern recognition, abstraction ability, thinking algorithms, and mathematical literacy skills. In addition, it is also necessary to develop the process of CT integration in learning both using unplugged and plugged based on the concepts and components of CT in this study. This study focuses on analyzing pre-service mathematic teachers' responses to describe the thought process involved in mathematical modeling using CT concepts.

Conflict of Interest

The authors declare no conflict of interest in this research.

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