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TPACK-based hybrid learning model design for computational thinking skills achievement in mathematics

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Abstract

Hybrid learning implementation is closely related with technology. In designing hybrid lessons, lecturers need to have both the pedagogical and content-related skills that make the best use of technology so that it also improves the students' skills, including their computational thinking skills. The purpose of this research is to examine whether a hybrid learning model based on Technology Pedagogy and Content Knowledge (TPACK) affects the computational thinking skills achievement in a valid, practical, and effective manner. This research is development research using the Plomp's model and is described in a qualitative descriptive manner. The participants were lecturers and 38 first-year students at Primary School Teacher Education Study Program of Padang State University. The instruments were validation sheets, practicality assessment sheets by lecturers, questionnaire sheets for students, and computational thinking skills test questions. The results of the validity test show that in terms of content, language, and e-learning practice, they all met very valid criteria with an average percentage score of 85.9%, 86.2%, and 84.1%, respectively. The practicality test results of model handbooks, Semester Lesson Plans, Lecture Program Units, computational thinking questions, additional material, and e-learning model meet the practical criteria with an average percentage score of 77.5%, 86.8%, 89.1%, 83.8%, 79%, and 82.4%, respectively. The average percentage of student assessment scores is 82.9% and meets the practical criteria. The results of the effectiveness test showed that 21.9% of students had reached the moderate level, 6.3% reached the low level, and 71.9% reached the very low level. This study recommends future researchers to develop a hybrid learning model based on TPACK to achieve other 21st-century abilities.

Keywords: Computational Thinking Skills, Hybrid Learning, Plomp's Model, Technology Pedagogy and Content Knowledge (TPACK)

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Social distancing was the norm during the COVID-19 pandemic and universities limited face-to-face lectures in class. Online learning collaboration in lectures was an alternative during the new normal, and it is even presumed to determine the financial sustainability of many universities in the next normal era (Hoofman & Secord, 2021; Xie et al., 2020). For this reason, the quality of online learning in the new normal era must be further improved (Mangkhang & Kaewpanya, 2021). One thing that plays an important role in improving the quality of online learning during the new normal is the use of technology (Haleem et al., 2022; Xiao, 2021; Wannapiroon, Nilsook, Jitsupa, & Chaiyarak, 2021). Integrating technology into learning is an absolute demand carried out by educators from lower and higher education. However, research results by Andarwulan, Al Fajri, and Damayanti (2021) show that educators are not fully prepared to carry out online learning. Many lecturers, even though they have found effective ways to implement online learning, admit that they felt stressed and found it challenging due to the rapid changes (Hew et al., 2020). This unpreparedness relates to the availability of learning content and the ability to use technology. There is still a need for improvements in the quality of online learning, especially those related to technology and content.

The recommended technology for online learning that has been widely used in tertiary institutions is the Learning Management System (LMS) (Alturki & Aldraiweesh, 2021; Hussein & Hilmi, 2016; Mtebe, 2018; Toquero, 2020; Zwain, 2019; Dorobat et al., 2019). Indonesian universities are no strangers to the use of LMS. Data shows that during the pandemic, especially at the tertiary level, LMS was used in 300 public and private universities in Indonesia (Kemendikbud, 2021). In other words, universities understand that there are many advantages of using LMS in learning, such as assisting e-learning in providing teaching materials or educational content regardless of time and place, facilitating discussions, planning online activities, and setting learning expectations (Bradley, 2021; Raza et al., 2021)

LMS is flexible to use in various learning models. World education experts have found that there are as many as 34 learning models (Li et al., 2020). Out of all the learning models, hybrid learning is recommended for use in tertiary institutions. Hybrid learning is a learning model that combines offline and online learning (Singh et al., 2021). Research shows that the use of hybrid learning has helped optimize learning during the pandemic (Elkhatat & Al-Muhtaseb, 2021; Sutisna & Vonti, 2020). In addition, hybrid learning is the best learning model to use in the three eras: during the pandemic, the vaccination era, and the post-pandemic (Singh et al., 2021). Based on the results of a meta-analysis of 39 previous primary studies regarding hybrid learning, hybrid learning was found to have a significant positive impact on students' understanding of mathematical concepts with an effect size of 0.867 in the moderate effect category (Helsa & Juandi, 2023). This shows that hybrid learning is an effective learning model, especially for learning mathematics. The use of hybrid learning should be integrated with the use of technology. Therefore, one approach that can complement lectures with hybrid learning is the Technological Pedagogical Content Knowledge (TPACK) approach.

TPACK is an approach to delivering subject matter by integrating technology during the learning process (Mishra & Koehler, 2006). For many educators, TPACK plays an important role in successful learning. TPACK processes must include the process of planning and implementing lecturer training programs to balance knowledge, pedagogical and technological content (Santos & Castro, 2021). This is closely related to technological developments that are currently rapidly developing, and it must be hand in hand with lecturers' competencies, which include not only pedagogical, professional, personality, and social competencies, but also technological competencies (Powell & Patrick, 2006; Voogt et al., 2013; Mouza, 2016). Based on the results of a meta-analysis of previous studies in mathematics lectures, the effect size of the influence of TPACK on the mathematical abilities of prospective teachers or pre-service teachers belonged to the high category (Helsa & Juandi, 2023). Thus, it is necessary to equip prospective teachers in tertiary institutions with TPACK ability. All lecturers are also expected to have this competency, including lecturers in mathematics education. However, research shows that mathematics education lecturers still need to improve their classroom competence, especially in using technology during lectures (Nordin et al., 2013). The use of technology is inevitable because almost all activities use technology extensively, one of which is widely used in computer technology. As the use of computer technology expands, the need for programming skills becomes even more relevant, and computational thinking becomes a much-need skill in the 21st century.

Computational thinking is viewed as a field that has the potential to support the development of individuals and society in a world that is developing rapidly and provides significant economic benefits (Cansu & Cansu, 2019). Moreover, computational thinking is a thinking process involved in formulating problems and solutions that are effective in processing information (Wing, 2011). Computational thinking is one of the abilities that need to be honed through practice and is one of the basic knowledge for high-level problem-solving abilities (Tim Penyusun Materi ITB, 2020). Computational thinking allows one to solve problems like a computer through decomposition processes, pattern recognition, abstraction, and algorithm design (Kidd & Morris, 2017). All these steps will help in solving various problems in a quick, precise, and effective manner. Even though it is closely related to computers, computational thinking can be used in various fields, such as language arts, mathematics, science, social science, and many more. In mathematics, computational thinking is classified as cognitive skills. The process begins by introducing students to solving complex and difficult problems and then turning them into simpler stages. One can also ask students to recognize existing patterns in the problem and then create a series of new stages to obtain a solution or draw conclusions from a simulation.

Computational thinking is currently one of the focuses tested in PISA's mathematical literacy exam (Zahid, 2020). The PISA framework related to mathematical literacy, which initially focused on basic calculation skills, was redefined by the OECD with due regard to very rapid technological advances (Anggraena, 2021). Based on PISA (*Programme for International Student Assessment*) (OECD, 2018), the average score for Indonesia's mathematical literacy ability is 379, and the result is 52 points below the average student in South East Asia. Based on the percentage, only 24% of students have a minimum competency level or more. More than 70% of Indonesian students are below the minimum competency level in mathematics and reading. There are still many students in Indonesia who are unable to understand simple reading or apply basic mathematical concepts. In the last 10 to 15 years, Indonesian students' PISA scores in reading and mathematics have not increased significantly. This indicates that there are large disparities between regions and between socio-economic groups in terms of the quality of learning.

Based on these results, Indonesia needs to work on improving students' mathematical literacy skills so they can reach the minimum PISA competency level. The next thing that needs to be considered is the inclusion of computational thinking abilities in the PISA mathematical literacy assessment. This ability needs to be developed starting from the primary level of education to tertiary education. One effort for long-term prospects that can be done is to improve the lecture process in tertiary institutions for student teacher candidates who will become better educators in the future.

Research shows that mathematics is one of the lessons that develop computational abilities (Cahdriyana & Richardo, 2020). However, integrating computational thinking in mathematics education lectures is not easy (Kallia et al., 2021). No one has yet to develop a hybrid learning model in collaboration with TPACK with a computational thinking orientation. Based on some of the studies above, this research focuses on developing a hybrid learning model using the TPACK approach that is oriented toward computational thinking for mathematics lecturers in the Primary School Teacher Education (PSTE) department.

METHODS

Research Type

This study is Research & Development using the Plomp's model from McKenney which includes three stages, namely the preliminary research phase, the prototyping phase, and the assessment phase (Plomp & Nieveen, 2013). An overview of the development process is presented in Figure 1.

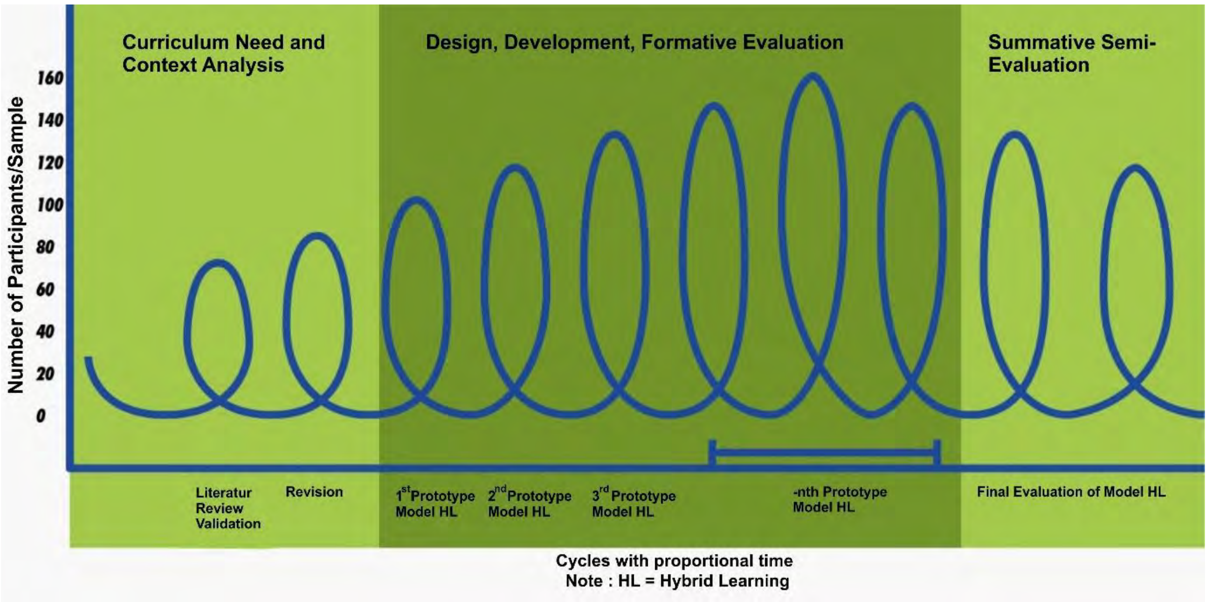


Figure 1. Learning model development cycle from McKenney (Plomp & Nieveen, 2013)

Development Procedure

In the preliminary research stage, a needs analysis and content analysis were carried out through a literature review, field study, and conceptual framework development to obtain the 1st prototype. In the prototyping phase, validation tests were carried out by experts. Suggestions and input are used as the basis for revising the product and the second prototype was produced. Then, the 2nd prototype was tried out in class and assessed for its practicality by practitioners and students. Suggestions and feedback from practitioners and students were also used as the basis for revisions and the 3rd prototype was produced. In the assessment phase, a posttest is carried out to see the students' CT skills achievement. At this stage, an effectiveness test was also carried out using the results of the post-test and interviews with students. Figure 2 is a flowchart of the performed development research.

Time and Place of the Trial

The trial was conducted in November and December 2022 with 32 first-year students from the PSTE department who took the Introduction to Mathematics course.

Data, Instruments, and Data Collection Techniques

The data collected includes validity, practicality, and effectiveness data with the following techniques and instruments (see Table 1).

Table 1. Recapitulation of instruments and data collection techniques

Type of Test	Aspects	Instrument	Results	Subject
Non-Test	Validity	Content validation sheet Language validation sheet E-learning validation sheet	Validity score	Lecturers

Type of Test	Aspects	Instrument	Results	Subject
	Practicality	Practitioners' assessment sheet	Practicality score	Lecturers
		Student assessment sheet	Practicality score	Students
Test	Effectiveness	Computational thinking skills test	Test score	Students

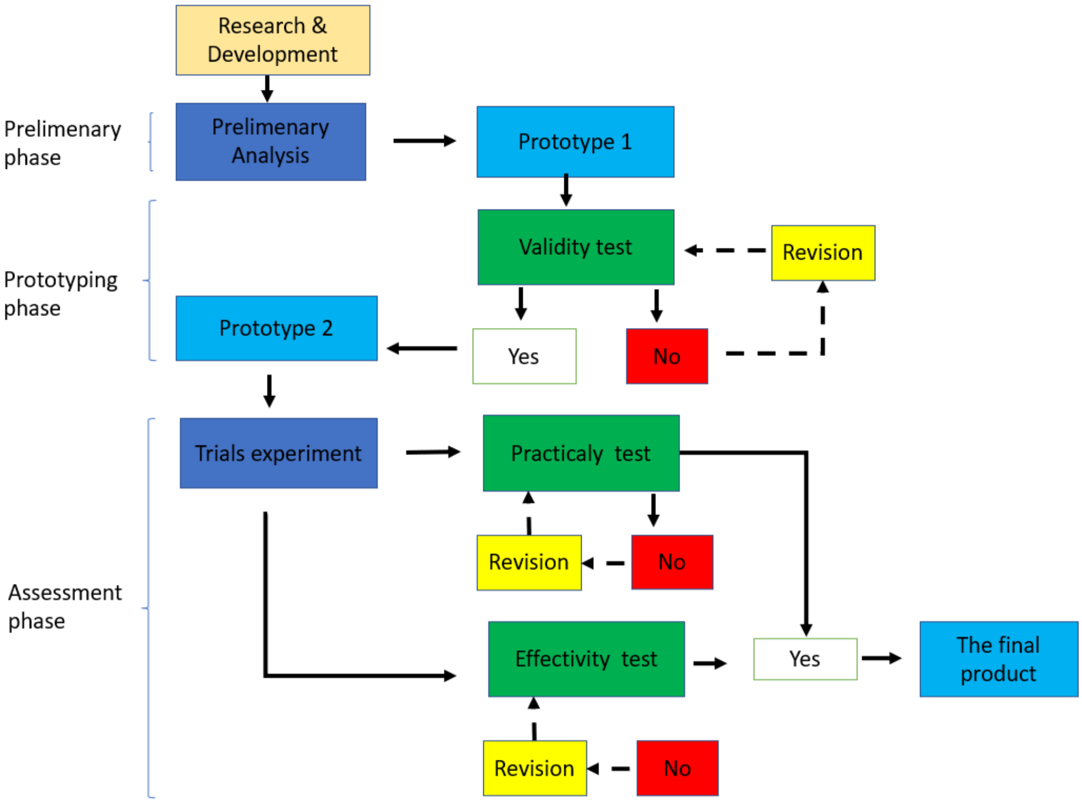


Figure 2. Research flowchart

Techniques of Data Analysis

Validity

Data validity assessment results were analyzed following these steps:

1) Calculating the assessment scores of all validators;
2) Calculating the value (%) of the validity of the score of the assessment results for each validator using the following formula (Akbar, 2017);

$$V_i = \frac{T_{Se}}{T_{Sh}} \times 100\% \qquad (1)$$

V_i	:	Percentage of validity of the i^th validator
T_{Se}	:	Total empirical score (sum score of the assessment by the validator)
T_{Sh}	:	Total expected score (maximum total score)

3) Calculate the value (%) of the combined validity of all validators with the following formula;

$$V_i = \frac{V_1 + V_2 + V_3}{3} = \ldots\% \tag{2}$$

4) Determining the validity criteria from the value (%) of the combined validity based on the validity criteria presented in Table 2;
5) Referring to the validity criteria in Table 2, the validity criteria of this study is in the range of 70.01% - 85.00% as the minimum limit for product validity, both for learning model handbooks, semester lesson plans, lecture program units, CT test questions, additional materials, and e-learning practice.

Table 2. Product validity criteria

No	Validity Score	Criteria
1.	85,01-100,00%	Very valid
2.	70,01-85,00%	Valid
3.	55,01-70,00%	Fairly valid
4.	37,01-55,00%	Less valid
5.	20,00-37,00%	Invalid

Practicality

The practicality data from the assessment of practitioners and students were analyzed by changing the quantitative data into qualitative data on a scale of five and then calculating the percentage. The criteria are determined based on Table 3.

Table 3. Product practicality criteria

No	Practicality Score	Criteria
1.	85,01-100,00%	Very Practical
2.	70,01-85,00%	Practical
3.	55,01-70,00%	Quite Practical
4.	37,01-55,00%	Less Practical
5.	20,00-37,00%	Impractical

Effectiveness

To further determine the effectiveness of a field trial, a one-shot case study design was performed. The form of the field trial design is shown in Figure 3. In this design, students were given a treatment of the TPACK-based hybrid learning model along with the products developed. At the end of the meeting, a posttest was given in the form of questions containing CT indicators.

X	O
Treatment	Posttest

Figure 3. One shot case study design in field trial

The effectiveness of the developed product is related to the computational thinking skills of the students as the research participants.

RESULTS AND DISCUSSION

Preliminary Research

Based on the Plomp's development model, the first stage to be carried out is preliminary research. At this stage, the results obtained from the meta-analysis on students' understanding of mathematical concepts turned out to have a significant positive impact after the application of hybrid learning. This is confirmed by the result that hybrid learning has an effect size of 0.832 or a moderate effect size on students' understanding of mathematical concepts with a P-value = 0.000 <0.05. Analysis was also carried out regarding TPACK. The results of the analysis show that TPACK has a high influence on mathematical ability. The combined average effect size is 1.06, meaning that TPACK has a significant impact on the mathematical abilities of prospective mathematics teachers. In addition, interventions of computer technology on students' CT skills had a modest positive effect (g = 0.401; p-value <0.05), in which computer technology interventions significantly improved students' CT skills. This shows that the learning process using computer technology is effective in improving students' CT skills.

The literature review shows that hybrid learning syntax had been used by previous experts. A new syntax was designed, and it refers to the TPACK-based hybrid learning model to achieve CT skills. Table 4 is the final syntax used in this study.

Table 4. Syntax of the Hybrid Learning Model in the final prototype

Stage	Syntax	Activity			
		Type 1		*Type 2*	
1	Implement The Hybrid Type	Asynchronous Online Learning	Students watch videos or materials provided in e-learning independently	Offline Learning	Offline learning in class
		Offline Learning	Offline learning in class	Asynchronous Online Learning	Students work on assignments through e-learning.
2	Using technology	Students learn and use technology to develop CT skills online.			
3	Examination	Students take quizzes through the e-learning portal.			
4	Evaluation	Offline quizzes and assignment			

A literature review was also carried out to detect which CT indicators were developed and used by previous researchers. The analysis found that indicators have many overlaps and are used in learning mathematics. The CT indicators used in this study are shown in Table 5.

Table 5. CT indicators in mathematics learning

No.	Components	Indicator
1.	Decomposition	• collect data using several computational tools • rearrange data in a meaningful and recognizable way • use computing tools to analyze data and draw valid conclusions • break down complex problems into smaller parts, • communicate and present data in a variety of ways

No.	Components	Indicator
2.	Pattern Recognition	• identify emerging patterns by conducting experiments and looking for commonalities among several problems • logically provide creative ideas for problem solutions in a variety of ways
3.	Abstraction	• find important information that is relevant to the problem raised critically • present problem-solving plans
4.	Algorithms Procedure	• develop step-by-step problem solutions or rules that must be followed in solving problems • explain the reasons for choosing the step • involve the use of tools in problem-solving
5.	Generalization	• identify and solve problems • conclude the solution to a problem • find their mistakes and fix them

Prototype Phase

The initial prototype developed in early in this research was five products, namely TPACK-based hybrid learning model handbooks for achieving CT, semester lesson plans (RPS), Lecture Program Unit, CT question instruments, and an e-learning model. The preparation of research products is in Figure 4.

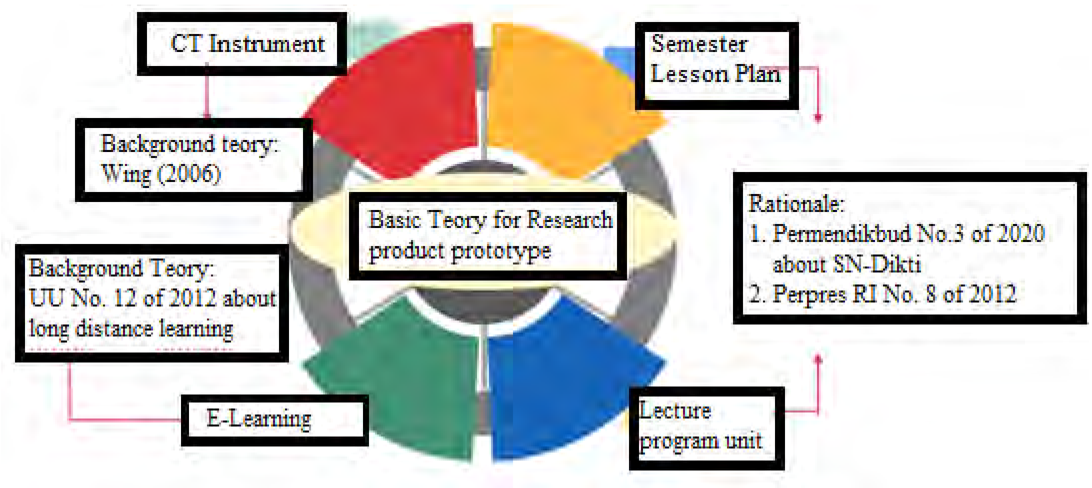


Figure 4. Basic theory in designing research product prototypes

Once these five products were designed, validation tests were then carried out based on content, language, and e-learning model, each validated by three different experts. The following results of the validation analysis of the prototype content are shown in Figure 5.

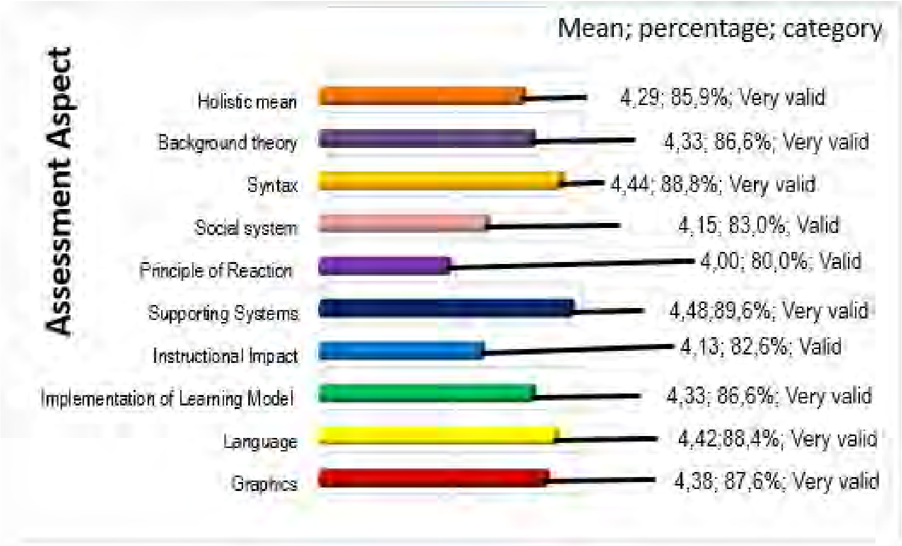


Figure 5. Content validation results of the TPACK-Based Hybrid Learning Model Prototype for computational thinking skills achievement

Based on Figure 5, the developed hybrid learning model prototype in general has very valid criteria with a total average of 4.30 and a feasibility achievement percentage of 85.9%. There are several suggestions related to graph theory, syntax, background, and model rationality. Therefore, it is concluded that the developed prototype No. 3 meets very valid criteria in terms of content. The results of the validity analysis in terms of language are presented in Figure 6.

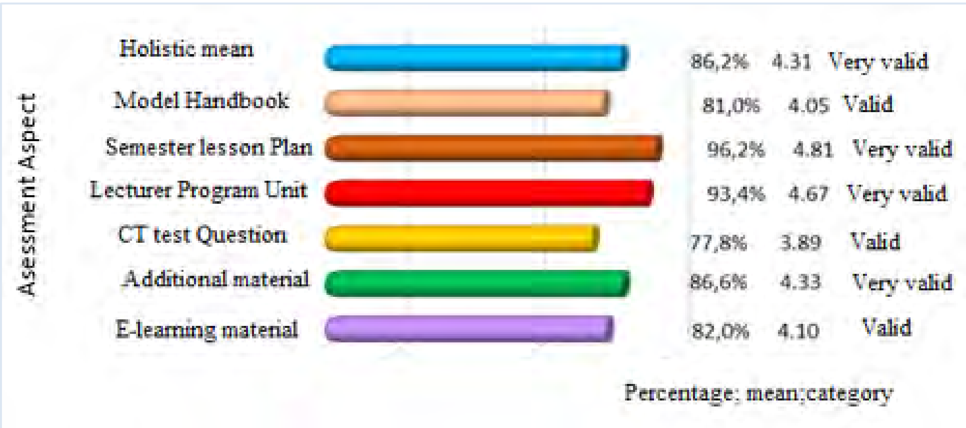


Figure 6. Language validation results of TPACK-Based Hybrid Learning Model Prototype for computational thinking skills achievement

Figure 6 shows that the developed prototype of the hybrid learning model handbook in general has very valid criteria with a total average of 4.31 and a feasibility achievement percentage of 86.2%. There are several suggestions regarding the selection of effective sentences, standardized words, and their conformity to *KBBI* (the official dictionary of standardized Indonesian language). In other words, it is concluded that the developed prototype No. 3 meets the very valid criteria in terms of language. The results of the validity analysis in terms of e-learning are presented in Figure 7.

Figure 7. E-Learning validation results on the TPACK-Based Hybrid Learning Model for computational thinking skills achievement

The developed e-learning prototype generally has very valid criteria with a total average of 4.21 and a feasibility achievement percentage of 84.1% illustrated in Figure 7. There are several suggestions related to graphics, content, and layout of e-learning. In other words, it is concluded that the developed prototype No. 3 meets very valid criteria in terms of the e-learning model.

Once the prototype is considered valid and feasible to use, it was then tested in an experimental class for its practicality. Practicality testing is based on the assessment of 3 practitioners and students. The following are the results of practicality assessments from practitioners.

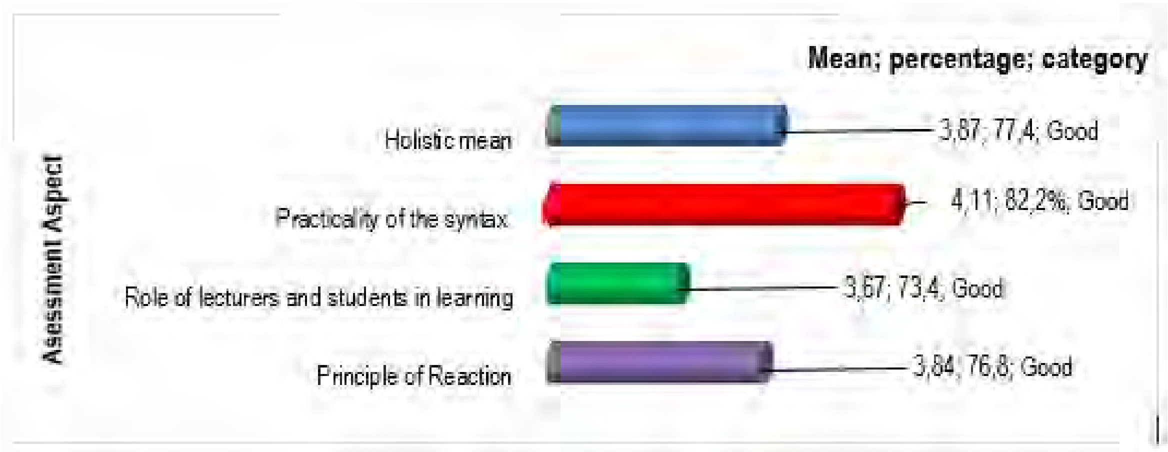


Figure 8. Practitioner practicality assessment results for Model Handbook

Figure 8 shows that the developed model book generally receives a good rating with an average of 3.87 and a practicality achievement percentage of 77.5%. Data from practitioners' evaluation of the semester syllabus prototype used in this study is shown in Figure 9.

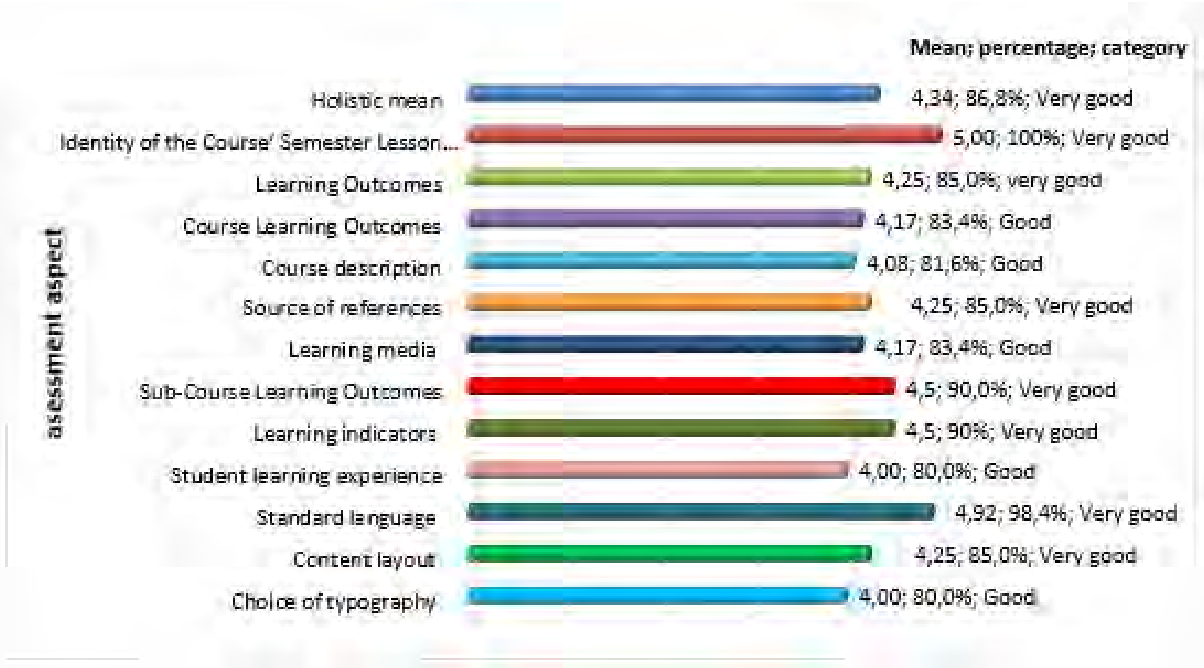


Figure 9. The results of the practicality assessment of lesson plans by practitioners

Figure 9 depicts the developed lesson plans receiving a very good rating with an average of 4.34 and a practicality achievement percentage of 86.8%. Data from practitioners' evaluation of the SAP prototype used in this study can be seen in Figure 10.

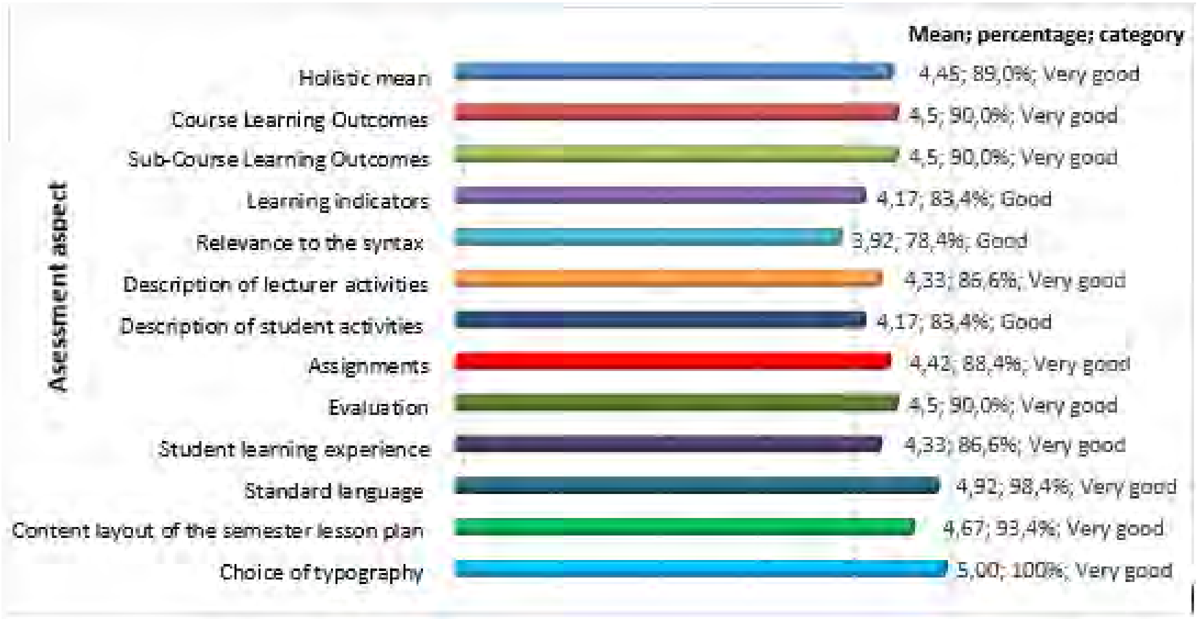


Figure 10. The results of the practicality assessment of Lecture Program Unit by practitioners

Figure 10 shows that in general, the developed SAP received a very good rating with an average of 4.45 and a practicality percentage of 89.1%. Data from practitioners' evaluation of the CT questions prototype used in this study is shown in Figure 11.

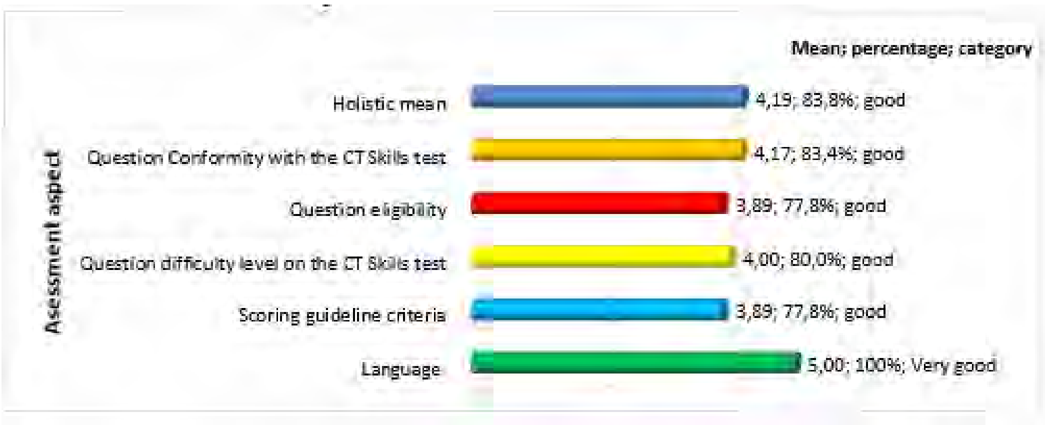


Figure 11. The results of the practicality assessment of CT questions by practitioners

The developed CT questions generally received a good rating with an average of 4.19 and a practicality achievement percentage of 83.8% as shown in Figure 11. Data from practitioners' evaluation of the additional material prototypes used in this study is in Figure 12.

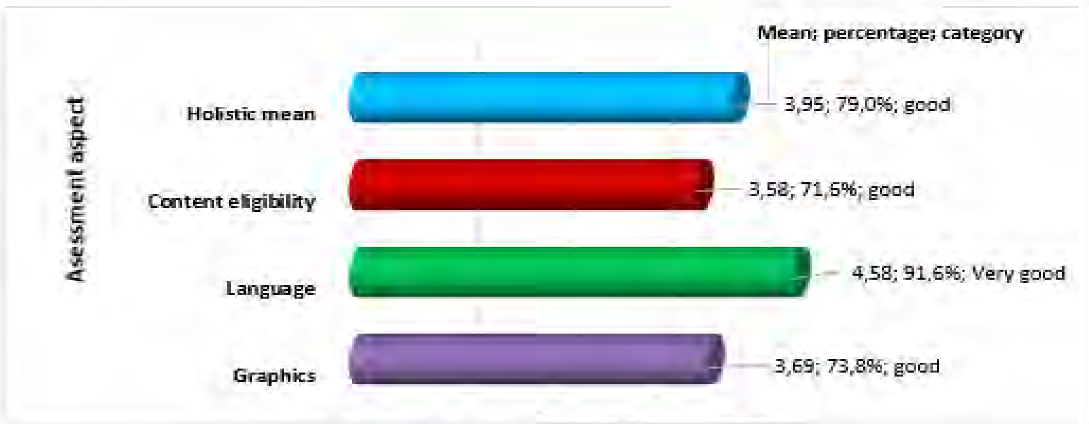


Figure 12. The results of the practicality assessment of the additional material by practitioners

Figure 12 explains that the developed additional material generally receives a good rating with an average of 3.95 and a practicality achievement percentage of 79%. Data from practitioners' assessment of the e-learning prototype used in this study is in Figure 13.

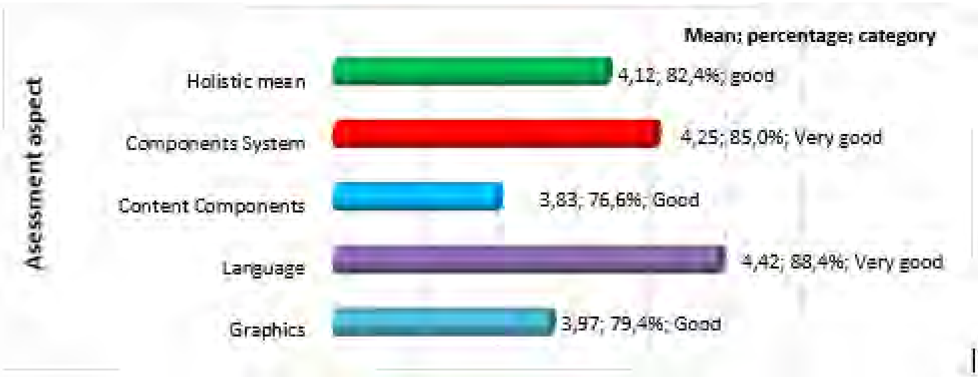


Figure 13. The results of the practicality assessment of e-learning by practitioners

Based on Figure 13, it is shown that in general, the developed e-learning receives a good rating with an average of 4.12 and a practicality achievement percentage of 82.4%. Data from the results of the practicality assessment of e-learning by students is shown in the following Figure 14. It shows that the developed e-learning receives a practical rating with an average of 4.15 and a practical achievement percentage of 82.9%.

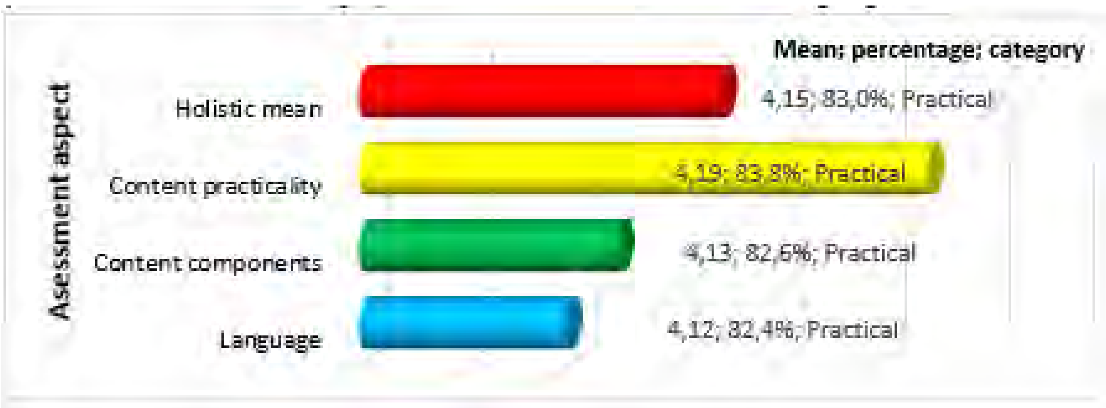


Figure 14. The results of the practicality assessment by students

Assessment Phase

Posttest was carried out in this stage to observe students' CT skills achievement through questions containing CT indicators. The post-test was given using seven questions containing CT indicators, which were adopted from Bebras questions (Tim Olimpiade Komputer Indonesia, 2018). Students were asked to work on five questions from all the questions available.

Table 6. Description of the CT indicators on the posttest questions

Question Number	CT Indicator
1	Decomposition, Abstraction, Pattern Recognition, Procedural Algorithm, Generalization
2	Decomposition, Abstraction, Pattern Recognition, Procedural Algorithm, Generalization
3	Decomposition, Abstraction, Pattern Recognition, Generalization
4	Decomposition, Pattern Recognition, Generalization
5	Decomposition, Abstraction, Pattern Recognition, Procedural Algorithm, Generalization
6	Decomposition, Abstraction, Pattern Recognition, Procedural Algorithm, Generalization
7	Decomposition, Generalization

The description of the indicators for each post-test item is shown in Table 6, while the post-test results can be seen in Table 7.

Table 7. Analysis of posttest results

	Posttest Data
Number of Students	32
Minimum Score	0
Maximum Score	44
Mean	15,35
Standard Deviation	14,21
Variance	202,07

The students' CT skill levels are divided into five levels, namely very high (80-100), high (50-79), moderate (30-49), low (20-29), and very low (0). -19). Table 8 shows the students' CT achievement levels based on the post-test results.

Table 8. Student CT skill achievement levels

CT Skills Level	Number of Students	Percentage
Very High	0	0,0%
High	0	0,0%
Moderate	7	21,9%
Low	2	6,3%
Very Low	23	71,9%
Total	32	100%

Hybrid learning or blended learning has been shown to have a significant impact on student academic performance (Hamdan & Amorri, 2022; Kazu & Yalçin, 2022; Lamport & Hill, 2012; Zeqiri et al., 2020). Meanwhile, technology plays an important role in achieving 21st-century skills (Yılmaz, 2021).The TPACK-based hybrid learning model was developed to facilitate the mastery of one of the 21st-century skills, namely computational thinking skills through a combination of online and offline learning that is planned pedagogically and following knowledge content. The syntax obtained is the result of an elaboration of the hybrid learning model syntax used worldwide by combining technological functions of both pedagogy and knowledge content. The syntax in question is described as follows.

The first stage in this model is to implement the hybrid type. At this stage, the lecturer can choose to use two hybrid types in lectures. The first type starts with asynchronous online learning, namely in the form of independent learning activities through videos and teaching materials provided in the e-learning portal. The goal is for students to try to understand the content of the material that will be discussed in class in advance so that students have initial knowledge. Research shows that independent study before lectures is proven to increase independence (Hockings et al., 2018). This stage will also increase student motivation as it encourages them to find out more about new and unfamiliar things they are prepared for in the classroom. The extra efforts students made before class has been proven to increase student learning satisfaction (Liborius et al., 2019).

After students study independently, on a set lecture schedule, face-to-face learning is then carried out. Face-to-face learning can also be done in a variety of ways. Lecturers can start with an explanation of the material and then continue with group discussions or other methods. Face-to-face learning aims to maximize student knowledge through questions they already have before class begins. In this activity, the lecturer acts as a facilitator in guiding students to discuss and explore the concept. The second type in the first stage begins with face-to-face learning in class. Then, while still in face-to-face learning, students open the e-learning portal and discuss in groups using the material provided in the e-learning portal.

The second stage in this model is using technology. This stage can be done either during face-to-face interaction in class or online. Students are guided to study and use the desired technological media. In this study, the programs used were Microsoft Excel, Unity, R Studio, and Scratch. These programs are used as a tool for learning material content, especially mathematics. They are expected to support the development of 21st-century skills, specifically computational thinking skills. Research proves that the use of technology has a major effect on CT skills. In addition, the implementation of online lectures also requires the use of technology, such as Zoom or other online meeting applications.

The next stage is examination. This stage is carried out within the range of one meeting and the next meeting. Students are given quizzes and assignments in the form of CT questions that have been provided in the e-learning portal. Student answers are immediately given feedback after completing the quiz. The e-learning portal provides scores and grades that the students achieved. Giving quizzes is considered very supportive of learning. Research shows that giving daily quizzes at every meeting has an impact on students' mathematical achievement (Naseem & Scholar, 2021; Simion, 2011). Providing feedback after giving quizzes can also provide valuable experience to students, demonstrate the professionalism of teaching lecturers in tertiary institutions, and indirectly increase student mathematical achievement (Ahea et al., 2016). Good feedback should fulfill several criteria, which include 1) making students understand the goals to be achieved in the form of good performance; 2) facilitating the process of self-assessment or reflection in learning; 3) providing quality information to students about their learning; 4) providing opportunities for further discussion to understand feedback; 5) inspiring and providing positive motivation; 6) providing opportunities to close the gap between current and desired performance; 7) providing information to related instructors and is used to assist learning; and 8) adopting various e-feedback techniques (Ahea et al., 2016).

The final stage is evaluation. At this stage, an evaluation is carried out in the form of quizzes and assignments that were previously done face-to-face. Evaluation is in the form of discussing parts that are generally not understood by the students. The role of the lecturer here is to guide students so that they find the right solution. Lecturers also train students to analyze CT questions by tapping into their reading literacy.

In relation to TPACK, in the first stage of the developed learning model, which is implementing the hybrid type, technology takes a role in the form of a D – M – T-based tetrahedron in which the material is presented by lecturers using technology in the form of video, PowerPoint, or other media. In the second stage, technology takes on two roles at once, namely the tetrahedron form based on Ms – M – T and the tetrahedron form based on D – Ms – T (see Figure 15).

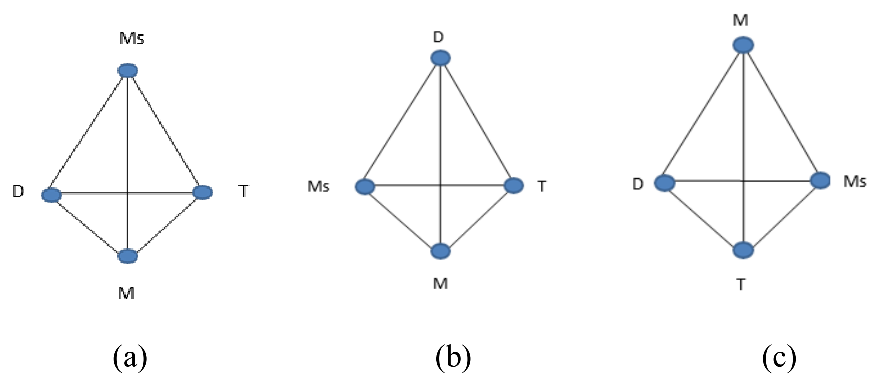


Figure 15. (a) D- M – T based didactic tetrahedron; (b) Ms – M – T based didactic tetrahedron; (c) A tetrahedron with D- Ms – T base

Trials in a class of first year PSTE students at Padang State University focused on the achievement of students' CT skills. We found that almost all students do not reach the five indicators that are expected to develop. The following is an example of student answers to post-test questions.

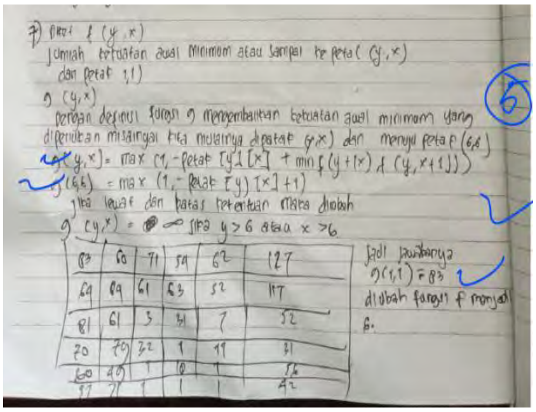
Problem 1:

In a game, a knight is initially in position (1,1) and is about to move to the position (6,6) to save a beautiful princess. Each game tile can contain vitamins or poisons, subject to the following conditions:

- *Squares containing vitamins are represented by positive numbers on the map, which are potions that will increase the strength of the knight.*
- *Squares containing poison are represented by negative numbers on the map, i.e., potions that will reduce the knight's strength.*

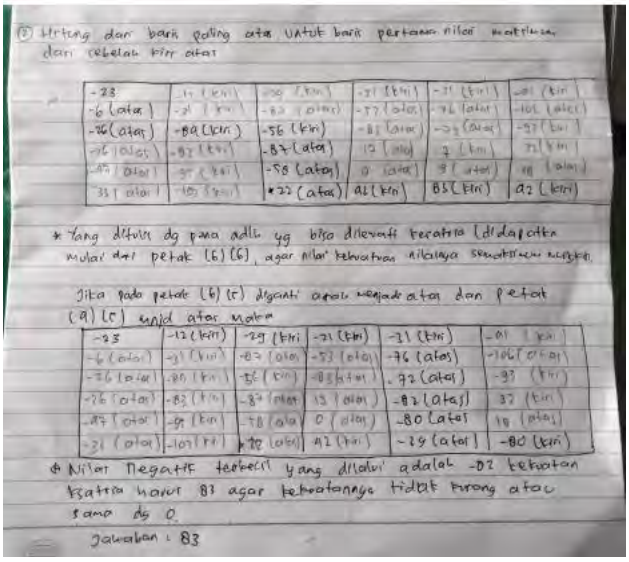
	1	2	3	4	5	6
1	-23	11	-17	8	-10	-10
2	17	-25	-58	-32	-45	-65
3	-20	-58	28	-30	4	-21
4	-10	-47	-31	100	-10	25
5	-11	-48	29	-17	2	-14
6	14	-70	80	20	41	-41

In this game, the knight can only walk east or south (cannot walk diagonally). Knights can never run out of power (negative or 0 power) during the game, including at the start of the game, and all potions on the squares the knight passes must be drunk. Determine the amount of initial strength of the drink that the knight must have at the start of the game so that the knight can save the princess and win the game!



Given that f(y,x)
Minimum starting strength sum or until the end of a map (y,x) and tile (1,1)
g(y,x)
By definition that function g returns the minimum initial strength required, e.g. we are in tile (y,x) and go to tile (6,6)
g(y,x) = max(1,-tile(y1[x]+min f(y+[x]+(y,x+1))
g(6,6) = max(1,-tile(y)[x]+1)
If it exceeds the provisions, then it is changed into
g(y,x) if y>6 or x>6
So, the answer is
g(1,1)=83 changed function f to g

(a)



Count from the top row for the first row of math values from the top left
Words in the table:
atas = up
kiri = left

What is written with the pen is what the knight can pass (obtained starting from the tile (6)(6), so that the strength value is as high as possible.
If we change the direction of tile (6)(5) into up and tile (4)(5) to top, then (see table)

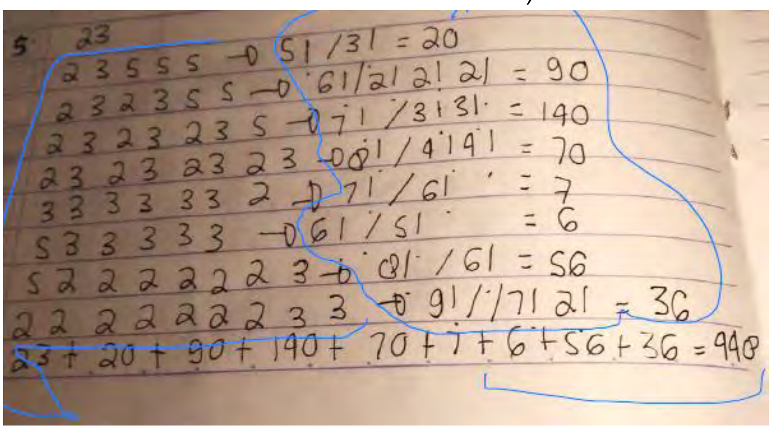
The smallest negative value that is passed is -83.
The knight's strength must be 83 so that his strength is not less or equal to 0.
Answer: 83

(b)

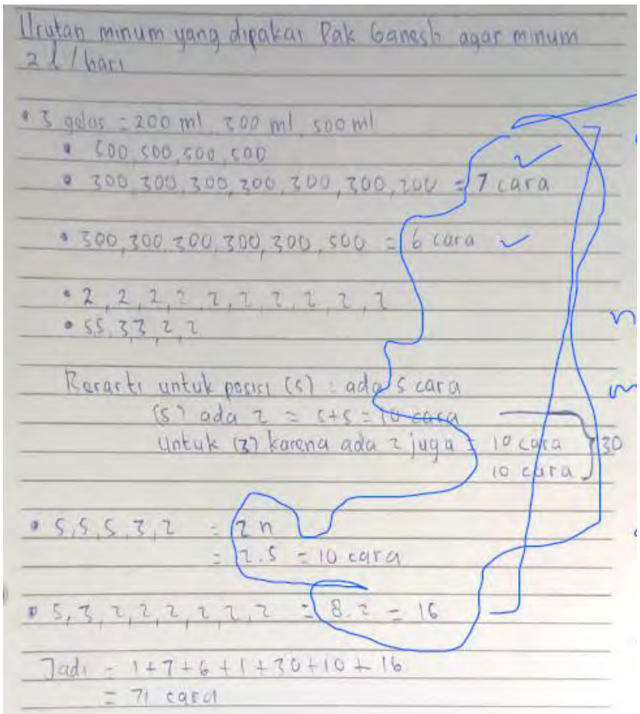
Figure 16. (a)(b) Sample of students' answer for question number 1

In question number one, students A and B succeeded in doing problem decomposition and pattern recognition in different ways. Student A finds patterns in the form of function formulas. Meanwhile, Student B solves it by making a table and entering the possible number of potions in the boxes that might occur according to the rules given. Students A can correctly use the procedure algorithm after finding a pattern or formula. Even though Student B did not show the formula used, the description of the process that was carried out succeeded in making him generalize the solution to the given problem. This shows that students' computational thinking skills develop in different ways (see Figure 16).

Problem 2:
As a martial artist, Mr. Ganesh should stay fit and not easily get sick. To stay healthy, Mr. Ganesh must drink 2 liters of water per day. Mr. Ganesh owns 3 glasses: one is 200 ml, one is 300 ml and the other is 500 ml. Determine the number of times Mr. Ganesh will drink the 3 glasses (you don't need to use all of them) if he wants to drink exactly 2 liters of water. (Note: drinking sequences 200-200-200-200-200-500-500 and 500-500-200-200-200-200-200 are considered different).



(a)



The drinking sequence used by Mr. Ganesh is to drink 2L/per day
gelas = glass
7 cara = 7 ways

Meaning that for position(s): there are 5 ways
(s) there are 2 = 5 + 5 = 10 ways
For (3) because there are 2 also = 10 ways

Thus,
= 1+7+6+1+30+10+16
= 71 ways

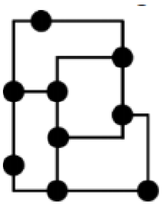
(b)

Figure 17. (a)(b) Example of student answers to question number 2

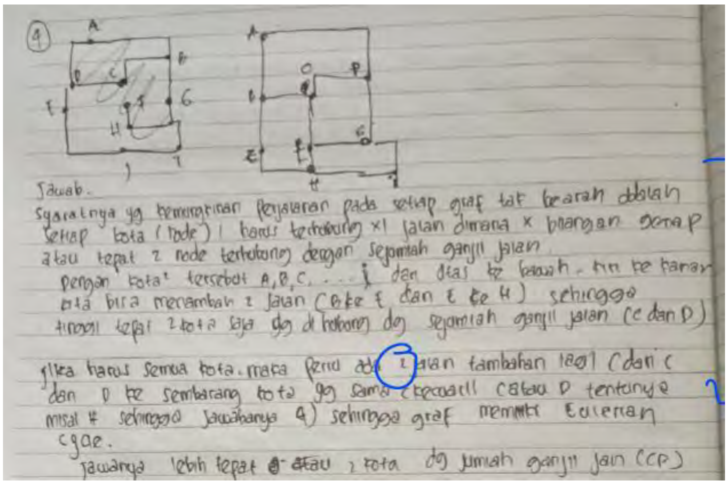
In question number 2, it can be seen that students A and B gave different processes and results. Student A succeeds in recognizing the pattern of the problems given so that it makes it easier for them to carry out the procedure algorithm correctly. As a result, the result he obtained was correct. On the contrary, Student B fails in finding a pattern. Student B was correct when he started explaining the possible fractions of 2 liters which equal 2000 ml. Then, Student B is also correct in the early pattern discovery steps. However, Student B did not complete the description of all possible glass combinations used. In general, the answers of the two students indicated that there was a development of computational thinking skills, especially in problem decomposition and abstraction indicators. The only problem is Student B did not finish the last step in recognizing patterns which results in incomplete procedural algorithms and generalizations (see Figure 17).

Problem 3:

The following picture is a road map between cities in the country of Wakanda.

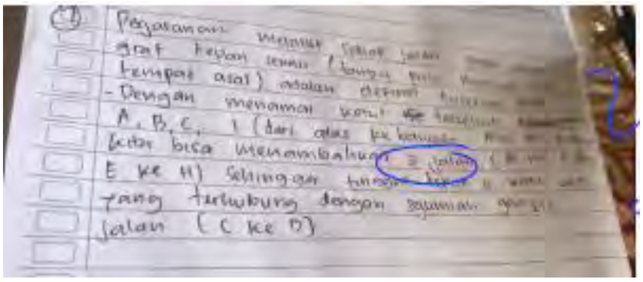


Since many tourists admire the beauty of the country of Wakanda, the king plans to build several additional roads so that tourists can go on an excursion to visit each city by passing each road only once. An additional road built can only connect exactly two cities, and two cities can be connected by more than 1 road. Determine the minimum number of additional roads that need to be built so that a tourist starting their trip from one city can use each inter-city road exactly once (no need to return to the city of origin)!



Answer:
The condition for the possibility of traveling on any undirected graph is that each city (node) I must be connected to an odd number of paths.
With these cities A, B, C, …. From top to bottom, left to right we can add 2 streets (B to F and E to H) so that the height is exactly 2 cities connected by an odd number of streets (C and D)
If it must be all cities then there need to be 2 additional roads (from C and D) to any of the same cities (except C or D of course, for example, H so the answer is 4) so the graph has Eulerian cgae.
The answer is precisely 2 cities with an odd number from CD.

(a)



Traveling through every path on a graph exactly once (without returning to the origin) is the Eulerian definition.
-By naming the cities A, B, C, … I (top to bottom, left to right) we can add 2 streets (B to F and E to H) so that there are exactly 8 cities connected by an odd number road (C to D)

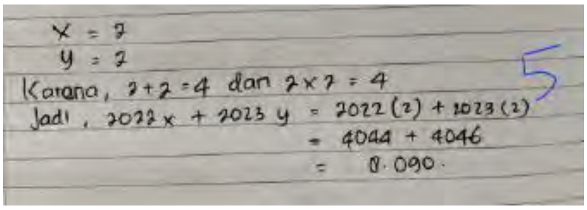
(b)

Figure 18. (a)(b) Example of student answers to question number 3

In question number 3, the two students succeeded in solving the given problem in different ways. The two students can simplify the problem with their language and then find patterns even if not with a certain formula. The two students used logical thinking by abstracting the problem. In the end, they can generalize to find the answer. The flow of thinking is almost the same, but Student A describes the problem in more detail than Student B. In other words, based on the student's answers, there is a development of computational thinking skills, especially for problem decomposition indicators (see Figure 18).

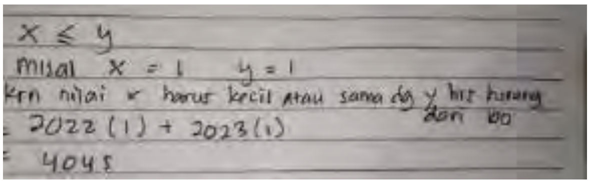
Problem 4:
Ms. Yullys kept the information of 2 positive integers x and y with x ≤ y and each number less than 100 as a secret. She only told Mr. Arman the sum of the two numbers and only the multiplication product of the two numbers Ms. Rinrin. Then a conversation ensued between Mr. Arman and Mrs. Rinrin, as follows:
Mr. Arman: "I don't know the value of the two numbers."
Mrs. Rinrin: "I don't know either."
Mr. Arman: "I know the number now."
Mrs. Rinrin: "Me too."

It should be noted that Mr. Arman and Mrs. Rinrin are very smart people, so they know the x value and the y value. Determine the value of 2022x+2023y!



Since 2+2 = 4 and 2 x 2 = 4
Then, 2022 x + 2023 y = 2022(2) + 2023(2)

(a)



If x = 1 y = 1
Since the value of x must be smaller or equal to y and must be less than 100

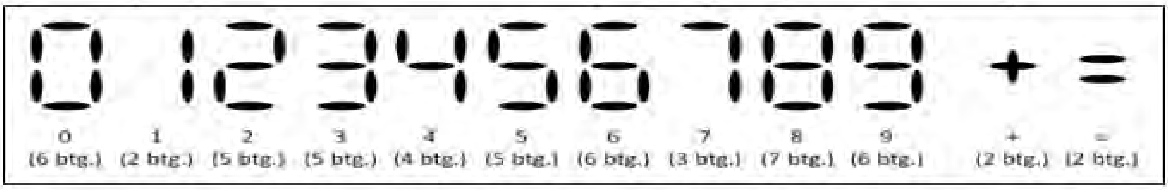
(b)

Figure 19. (a)(b) Example of student answers to question number 4

Question number 4 is quite difficult because it uses language that requires deep thought to decompose the problem. From the answers of the two students, it can be seen that Student A understand the problem posed and get important information to find patterns. The keyword of this problem is that when the two numbers are added and multiplied, the result is the same. Student B can only understand part of the information related, and that the two numbers must be equal or one smaller than the other and must be less than 100 (see Figure 19). From the answers above, students' computational thinking skills are shown to have developed, especially problem decomposition and pattern recognition.

Problem 5:

Toothpicks at TOMI Fried Chicken are often used as toys for customers. One day, because he was bored waiting for his order, Mr. Arman made a simple mathematical equation using 15 toothpicks that were on his desk. The mathematical equation created by Pak Arman can only contain the symbols in the following image, along with the number of toothpicks needed to make each symbol. A mathematical equation is a string formed by connecting mathematical symbols that can be used, for example, 1 + 1 = 2 and 1 + 4 = 2 + 3. Consider the following figure:

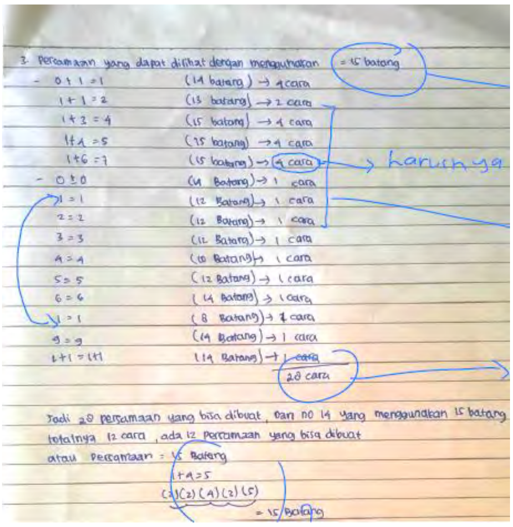


The mathematical equation formed by Mr. Arman must meet the following criteria:

- *The math equation is made with less than or equal to 15 toothpicks.*
- *The mathematical equation contains exactly one '=' (equal to) symbol.*
- *The left and right fields contain at least one numeric symbol: {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}.*
- *The value of the sum or the number on the left side is the same as the value of the sum or the number on the right side.*

- *A number symbol cannot appear right next to another number symbol, each number being one digit.*
- *The '+" symbol can only appear between two numeric symbols.*

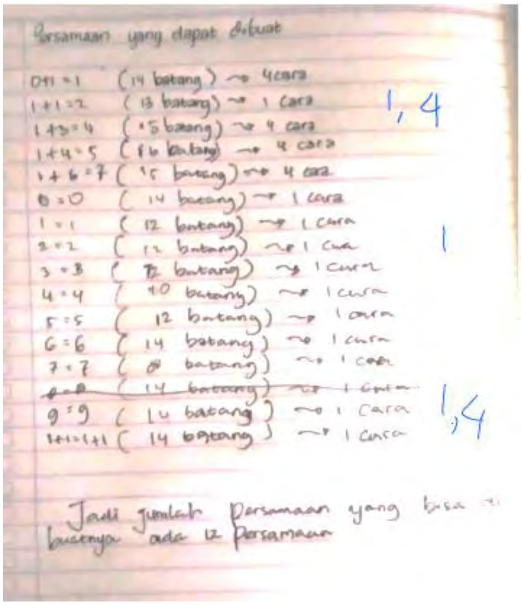
Determine how many different strings of mathematical equations Mr. Arman can make! (Note: If the strings representing the equations are different, they are counted twice. For example, the equations "1 + 1 = 2" and "2 = 1 + 1" are counted as two equations).



The equation that can be determined using = 15 sticks
Batang = stick
cara = way

So, 28 equations can be made from the number 4 using 15 sticks in a total of 12 ways, and 12 equations can be made
Or the equation = 15 sticks
1+4 =5
(2)(2)(4)(2)(5) = 15 sticks

(a)



equations that can be made
batang = stick
cara = way

So, the number of equations that can be made is 12 equations

(b)

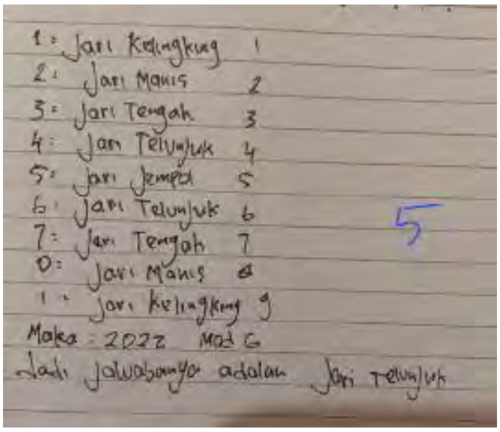
Figure 20. (a)(b) Example of student answers to question number 5

In question number 5, the two students tried to trace the patterns that emerged using the criteria given in the questions (see Figure 20). Student A errs a few steps but eventually finds a generalization of the problem. Meanwhile, Student B had difficulty bringing out all the equations. There are some equations left out, so the answer is wrong. In this problem, students' computational thinking skills are starting to develop, especially in pattern recognition.

Problem 6:

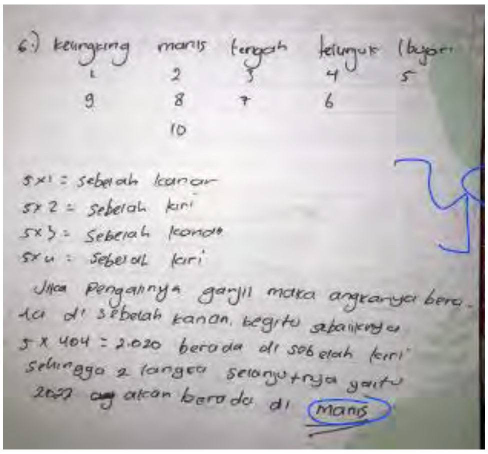
Mr. Arman is a person who likes puzzles. One day he thought of counting from 1 to 2022 using his fingers as shown in the image below:

Based on the picture, determine which finger is represented when Mr. Arman calculates the number 2022.



1 = little finger 1
2 = ring finger 2
3 = middle finger 3
4 = index finger 4
5 = thumb 5
6 = index finger 6
7 = middle finger 7
0 = ring finger 8
1 = little finger 9
Then 2022 modulo 6
So, the answer is the index finger

(a)



little finger ring finger middle finger index finger thumb
1 2 3 4 5

5x1 = right
5x2 = left
5x3 = right
5x4 = left
If the multiplier is odd, then the numbers are on the right and vice versa
5x400 =2020 is on the left so the next 2 numbers i.e. 2022 will be on the ring finger

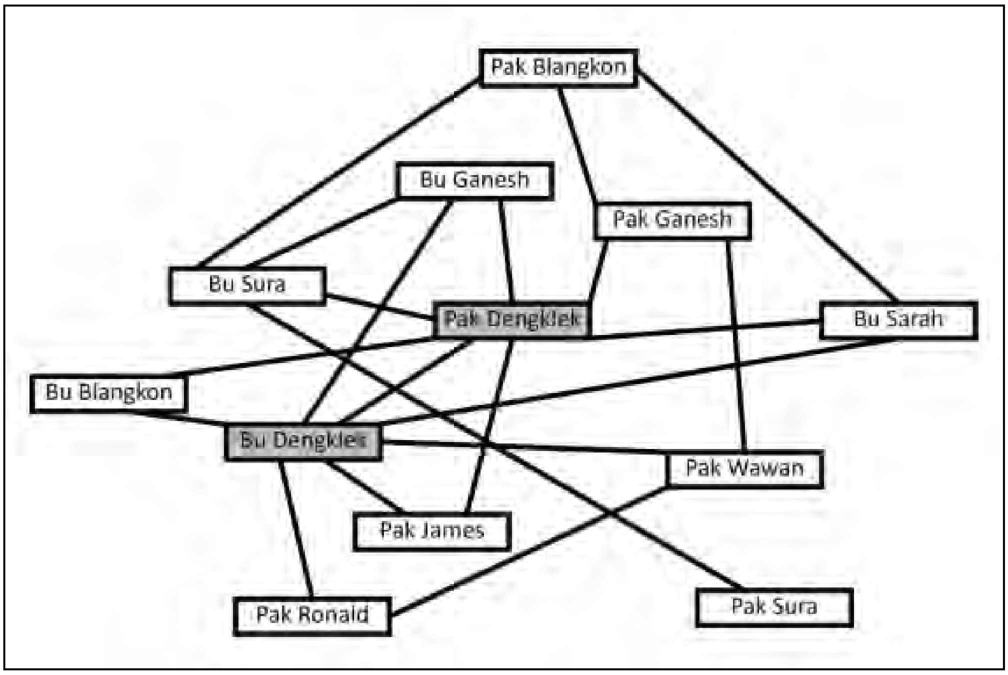
(b)

Figure 21. (a)(b) Examples of student answers to question number 6

In problem number 6, Student A uses the concept of modulo to solve the problem. In this case, Student A succeeds in decomposing the problem so that he finds repetitions that are indeed used in the modulo concept. Meanwhile, Student B uses the multiplication concept of 5 which is the basis of the modulo concept. However, Student B made a mistake when doing the procedural algorithm to calculate the number 2022. The two students show that their computational thinking skills began to develop, especially in problem decomposition and pattern recognition indicators (see Figure 21).

Problem 7:

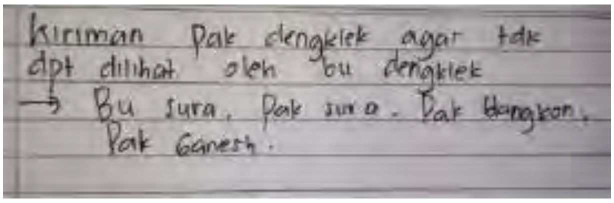
The image below describes Mr. Dengklek with his friends who sign up on a social media platform called TomiBook.



On TomiBook, a line signifies the friendship between two people. On this social media, someone can upload, like, or share the uploaded photos. The rules are as follows:

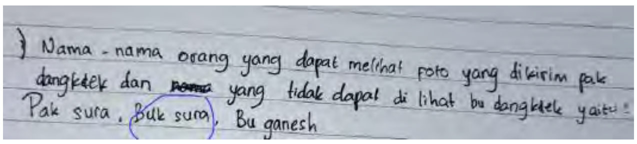
- *Someone who uploads a photo can choose to share it with friends which one specifically?*
- *If someone likes your photo, all their friends can see your photo.*

Mr. Dengklek wants to upload a photo, but the photo is not supposed to be seen by Mrs. Dengklek. To whom can Mr. Dengklek share his photo so that Mrs. Dengklek will never see it? (Write down the names of people who can see the photos sent by Mr. Dengklek and cannot be seen by Mrs. Dengklek).



Mr. Dengklek should send it to these people so that Mrs. Dengklek could not see it
-□ Mrs. Sura, Mr. Sura, Mr. Dengklok, Mr. Ganesh

(a)



The names of people who can see the photos sent by Mr. Dangklek and those who cannot be seen by Mrs. Dangklek are Mr. Sura, Mrs. Sura, Bu Ganesh

(b)

Figure 22. (a)(b) Example of student answers to question number 7

In question number 7, almost all students were wrong in finding the solution to the problem. This problem only has problem decomposition and generalization indicators. The possible cause is the students misunderstood the pictures given (see Figure 22). The students also failed to carefully observe the relationship between each existing photo. One other reason is that students are less critical in reading the information provided so they missed some information.

CONCLUSION

Learning with the hybrid model requires the support of technological mastery both in terms of pedagogy and the context of knowledge so that it can develop students' computational thinking skills. The research results concluded that the TPACK-based hybrid learning model affects computational thinking skills in a valid, practical, and effective manner. The results of the validity test show that in terms of content, language, and e-learning model, they meet very valid criteria with an average percentage score of 85.9%, 86.2%, and 84.1%, respectively. The practicality test results from the assessment of three practicing lecturers show that model handbooks, Semester Lesson Plans, Lecture Program Units, computational thinking questions, additional material, and e-learning model meet the practical criteria with an average percentage score of 77.5%, 86.8%, 89.1%, 83.8%, 79%, and 82.4%, respectively. Then, the average percentage of student assessment scores is 82.9% with practical criteria. The results of the effectiveness test showed that 21.9% of students had reached the moderate level, 6.3% reached the low level, and 71.9% reached the very low level. However, this research was only conducted on Primary School Teacher Education (PSTE) students in Introduction to Mathematics course. In addition, this research only looks at students' existing computational thinking skills. This study has not yet aimed to improve computational thinking skills. It also focuses on only one 21st-century skill, namely computational thinking skills. Therefore, this study recommends future researchers to explore the computational thinking skills achievement in different subjects. Further research to develop a hybrid learning model based on TPACK to achieve other 21st-century skills is also suggested.

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Declarations

Author Contribution	:	YH: Conceptualization, Writing-Original Draft, Visualizations, Editing, and Templating. T: Visualizations, Review Formal Analysis, Editing, and Supervision. DJ: Visualizations, Review Formal Analysis, Editing and Supervision.
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Conflict of Interest	:	The authors declare no conflict of interest.

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