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Development of Interactive Learning Multimedia Based on Android Integrated with STEM Heat Material to Improve Students' Computational Thinking

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Abstract: This study aims to produce an interactive learning multimedia application product based on Android integrated with STEM heat material that is valid, practical, and effective in improving students' computational thinking skills. This research and development was carried out using a 4D model consisting of defining, designing, developing, and disseminating. This study uses a mixed methods concurrent embedded model consisting of five stages of data collection, namely qualitative data collection followed by quantitative data collection followed by providing interventions in the form of qualitative data collection followed by quantitative data collection and finally qualitative data collection. The trial design used was a non-equivalent pre-test post-test control group design. The subjects of the study were 64 junior high school students, 32 in the experimental class and 32 in the control class. The results of the study showed that the resulting product was stated as: very valid (94%) by material experts, (95%) by media experts; very practical to use in learning by students (91%), with a very high level of learning implementation, namely (94.57%); effective in improving students' computational thinking with high n-gain (0.77) and effect size with criteria of (91%). Based on the results of research and data analysis, it shows that the developed product can be used in learning heat material to improve students' computational thinking abilities.

Keywords: Android; Computational thinking; Interactive learning multimedia; STEM

Introduction

In this digital era, the problems that people face are increasingly complicated and complex, so they require better skills in finding solutions. However, there are still not many learning practices that aim to improve students' problem-solving skills (Ansori, 2020). Problem-solving skills are one of the 21st-century skills that are important for students to master as preparation for facing the Industrial Revolution 4.0 (Dewi et al., 2021). The approach that can be applied to train students' problem-solving skills is the computational thinking approach (Dewi et al., 2021; Yuntawati et al., 2021). Computational thinking is the ability to think to solve problems in a comprehensive, logical and structured manner (Wing, 2006). Computational Thinking as a way of understanding and solving complex problems using computer science techniques and concepts such as decomposition, pattern recognition, algorithms and abstraction is considered by many experts to be one of the abilities that support many dimensions of 21st century education (Ansori, 2020; Maharani, 2020). Four basics in computational thinking, namely decomposition, pattern recognition, abstraction, and

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algorithms (Liem, 2017). The problem-solving process can be supported through appropriate media (Ardiani, 2022). The use of media by teachers should be based on the design or learning plan that will be implemented so that the principle of use needs to be linked to the needs and characteristics of students (Rasvani & Wulandari, 2021).

In the context of science learning, especially in heat material, there are several basic concepts that are difficult to observe directly or cannot be seen with the naked eye, such as particle movement. However, this challenge can be overcome through the use of appropriate learning media. Students can explore a deeper understanding of science concepts through images, videos or visual simulations, allowing them to understand phenomena that cannot be physically observed, This opens the door to a more dynamic learning experience and makes it easier for students to understand abstract concepts in the heat material more effectively.

Another solution that can be done to improve the effectiveness of learning in improving students' computational thinking is to use interactive learning multimedia integrated with STEM (Science, Technology, Engineering, and Mathematics). This integration allows students to be actively involved in learning, connect science, technology, engineering, and mathematics concepts in relevant and interesting contexts, and have problem-solving skills (Irawan et al., 2022; Lin et al., 2021; Widya et al., 2019). STEM in this study is the application of science concepts related to heat material by applying the principles of heat transfer from solar energy which is implemented in a solar car manufacturing project.

Integrated interactive learning multimedia not only provides a more holistic learning experience, but also enables the development of various skills, especially computational thinking skills. which is needed in the 21st century. The multimedia extension product developed in this study is in the form of an apk and can be installed on a smartphone android, so that students can easily learn anytime and anywhere (Alhafidz & Haryono, 2018; Rachma et al., 2020).

This study aims to produce an interactive learning multimedia application product based on Android integrated with STEM heat material that is valid, practical, and effective in improving students' computational thinking abilities. Previous studies have developed a lot of android-based interactive learning multimedia. For example, research by Kartini & Putra (2021) who succeeded in designing an interactive learning application with a main menu consisting of material, exercise and quiz menus, Yektyastuti & Ikhsan (2016) designed interactive learning with a main menu consisting of competency, material, exercise and evaluation menus, Adnyaswari et al. (2022) designed interactive learning with a main menu consisting of material, video, LKPD, and quiz menus, Astuti et al. (2017) designed interactive learning with a main menu consisting of material menus, learning videos and practice questions. The application has shown effectiveness in increasing student engagement and facilitating access to learning materials. The novelty in this study is the use of Augmented Reality (AR) in MPI (Interactive Learning Multimedia), Then there is the integration of STEM solar car manufacturing projects in MPI, and the questions used are questions with Computational Thinking capabilities. in order to develop critical thinking and problem-solving skills. Thus, this study not only expands the scope of previous studies, but also provides new contributions in combining cutting-edge technology and innovative pedagogical approaches into Android-based digital learning media.

Method

The method used in this research is a mixed method. with embedded experimental model design. Mixed methods is a research method that uses a combination of quantitative and qualitative research. (Creswell & Creswell, 2017). Combination model research method embedded, is a research method that combines the use of quantitative and qualitative research simultaneously/together (or vice versa), but the weights of the methods are different.

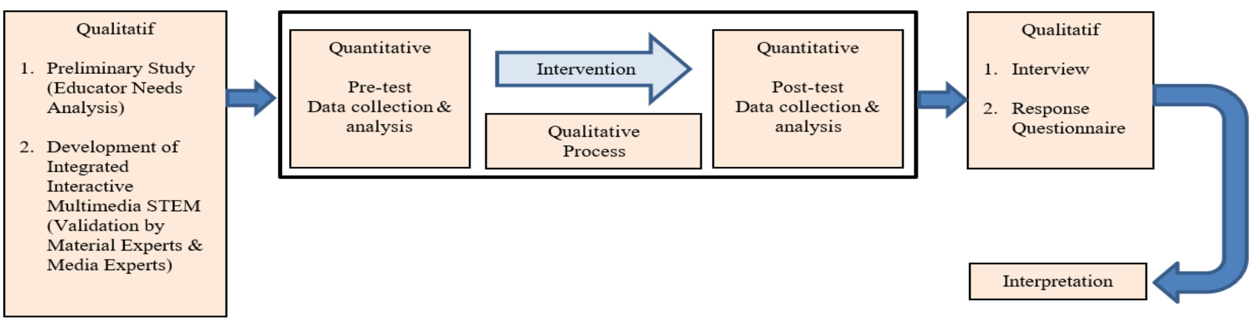

Figure 1. Research design scheme

This study consists of five stages of data collection, namely qualitative data collection followed by quantitative data collection followed by providing interventions in the form of qualitative data collection followed by quantitative data collection and finally qualitative data collection. In the first stage of qualitative data collection, a preliminary study was conducted. The researcher conducted an analysis of educators' needs for interactive learning multimedia based on android integrated with STEM. by distributing questionnaires to science teachers in Lampung Province. Researchers used questionnaires as the main data collection tool. Through this instrument, science teachers in Lampung Province were asked to fill out a questionnaire related to their experience in using interactive learning multimedia based on Android integrated with STEM. This includes their understanding of the specific needs of learning media, the obstacles they may face, and strategies to improve teaching and learning in the field of computational thinking.

The next step is to develop the product with the Four D Model device development model suggested by Thiagarajan et al. (1974). This model consists of 4 stages of development, namely Define, Design, Develop, and Disseminate.

Activities at the Define stage are often called needs analysis. In general, in this definition, development needs analysis activities are carried out, product development requirements that are in accordance with user needs and Research & Development (R&D) models that are suitable for developing products. Analysis can be done through literature studies or preliminary research. Thiagarajan et al. (1974) analyzes 5 activities carried out at the define stage, namely: front end analysis, learner analysis, task analysis, concept analysis and formulation of learning objectives/specifying instructional objectives.

Design stage aims to design learning tools. Thiagarajan et al. (1974) divide the design into four steps that must be carried out at this stage, namely: criterion-test construction; media selection that is in accordance with the characteristics of the material and learning objectives; format selection, namely reviewing the existing teaching material formats and determining the format of teaching materials or media to be developed; and making an initial design according to the selected format.

At the Develop stage (media development), this stage is carried out to create interactive learning multimedia (text, images, audio, video, LKPD, Augmented Reality, Questions) in accordance with the content framework of the results of the curriculum and material analysis, after the media is developed the next stage is to combine the media using the Smart App Creator (SAC) application. SAC is one of the software that can be used to make iOS-based applications and Android that can be designed without code programming and can also be made with HTML5 and .exe formats (Widiastika et al., 2021). The next stage is to realize the learning media product. in the form of .apk files. Media This learning is made in a standalone format that can be installed and run offline (without connection) internet) or online on smartphones/mobile phones with an Android system.

In this stage, validation tests and trials of learning multimedia are carried out. interactive android-based. Thiagarajan et al. (1974) divides the development stage into two activities, namely: expert appraisal and developmental testing. Expert appraisal is a technique to validate or assess the feasibility of a product design. In this activity, an evaluation is carried out by experts in their fields. The suggestions given are used to improve the material and learning design that has been prepared. Developmental testing is an activity to test the product design on the actual target subjects.

During this trial, response data, reactions or comments from the target users of the model are sought. The results of the trial are used to improve the product. After the product is improved, it is tested again until effective results are obtained. Activities carried out in the process of analyzing validity data that is with method evaluate product development device learning done through an evaluation checklist on sheet validation product based on aspects /criteria evaluation with a grid instrument as in Tables 1 and 2, the validity criteria for Android-based interactive learning multimedia can be seen in Table 3.

Table 1. Material expert assessment questionnaire grid

Aspects/Indicators	Number of Assessment Items
Grammar	3
Main Material	9
Supporting Materials	3
Worksheet	3
Question	3

Table 2. Media expert assessment questionnaire grid

Aspects/Indicators	Number of Assessment Items
Android application caption/display	3
Main Material	4
Supporting Materials	3
Worksheet	2
Question	2

$$\text{Percentage} = \frac{\text{Score}}{\text{Maximum score}} \times 100\ \% \quad (1)$$

The dissemination stage (spread) is done by socializing interactive learning multimedia through distribution to teachers and students. In the media development process, the dissemination stage is a step to disseminate information and introduce interactive learning multimedia to related parties, especially teachers and students. Socialization is carried out with the aim of educating and guiding them about the effective use of teaching materials /media that have been developed.

Table 3. Validity criteria for learning multimedia interactive android-based

Validity Criteria (%)	Validity Level
81 – 100%	Very valid, can be used without revision
61 – 80.9%	Valid, can be used but needs revision
41 – 60.9%	Less valid, recommended not to use because it needs major revision
21 – 40.9%	Invalid, may not be used

In the second stage, namely the implementation stage of the developed research model. During the implementation process, systematic monitoring and evaluation are carried out to assess the extent to which the model is able to increase student involvement, understanding of the material, and learning outcomes. This effectiveness test uses evaluation instruments, such as learning outcome tests. Effectiveness testing can be carried out with the type of research using a quantitative approach with a non-equivalent quasi-experimental research method pre-test post-test control group design (Creswell & Creswell, 2018).

Group A	O_1	X	O_2
Group B	O_3		O_4

Figure 2. Non-equivalent research design pre-test post-test control group design

Group A: Experiment group
Group B: Control group
$O_1 = O_3$: Pre-test
$O_2 = O_4$: Post-test
X: Treatment in the experimental group (learning using interactive learning multimedia based on Android integrated with STEM).

The target or subject of the research population in this study is the 7th-grade students of SMP IT Insan Robbani Kotabumi, North Lampung, consisting of class VII A, VII B, and VII C. The sample was determined using purposive sampling by selecting two classes with similar/equivalent academic profiles. The research sample consisted of students from class VII A (32 students) as the control class and class VII C (32 students) as the experimental class. The experimental class used the Problem-Based Learning (PBL) model and the developed media, which was an interactive Android-based STEM-integrated multimedia learning tool, while the control class used conventional (lecture-based) learning with PowerPoint (PPT) as the media.

At the beginning of learning, a pre-test is conducted as an initial step to identify and measure the level of students' initial computational thinking abilities. This pre-test aims to determine the extent of students' understanding of basic concepts in computational thinking, such as problem solving in the form of problem decomposition, pattern recognition, algorithmic thinking, and abstraction. The results of this pre-test will provide a comprehensive picture of students' readiness, so that teachers can adjust methods, materials, and learning approaches that are more effective and in accordance with students' needs.

In the third stage, the author used an observation sheet of the implementation of learning using STEM-integrated interactive learning multimedia as qualitative data. Qualitative data at this stage includes an analysis of the use of the developed media, namely the application of STEM-Integrated Android-Based Interactive Learning Multimedia in learning heat material. This model is designed to improve understanding of the concept of heat through an approach that combines science, technology, engineering, and mathematics interactively. Through the use of Android-based multimedia, it is hoped that students can more easily understand physics concepts related to heat with a more interesting and meaningful learning experience. To evaluate implementation learning, there is a number of criteria that have been set, which is more complete can be seen in the table following:

Table 4. Learning implementation criteria

Percentage (%)	Criteria
0.0 – 20.0	Very low
20.1 – 40.0	Low
40.1 – 60.0	Currently
60.1 – 80.0	Tall
80.1 – 100.0	Very high

$$\text{Percentage} = \frac{\text{Score}}{\text{Maximum score}} \times 100\ \% \qquad (2)$$

In the fourth stage, a post-test was conducted to evaluate the extent to which the application of the developed model has an effect on improving students' computational thinking skills as quantitative data. The results of this post-test are expected to provide an objective picture of the effectiveness of the model in improving computational thinking skills and provide insight for further development in the learning process.

The results of the pre-test and post-test were then tested for normalized gain (N-Gain) to see the effectiveness of the android-based interactive learning multimedia. Normalized gain or abbreviated as N-Gain is a comparison of the actual gain score with the maximum gain score (Hake, 1998). The calculation of the normalized gain score (N-Gain) can be expressed in the following formula:

$$\text{N-Gain}=\frac{\text{Posttest Score-Pretest Score}}{\text{Ideal Score-Pretest Score}} \quad (3)$$

Table 5. N-Gain value acquisition categories

N-Gain Value	Category
$g > 0.7$	Tall
$0.3 \leq g \leq 0.7$	Currently
$g < 0.3$	Low

Pre-test and post-test scores are also used to test the level of significance of the treatment given to the experimental group. This test is carried out using the Analysis of Covariance (ANCOVA) statistical test, which allows control of the covariate variables, in this case the pre-test score, in order to obtain a more accurate estimate of the treatment effect. The results of the analysis are seen from the significance value (Sig.) to determine whether the differences between groups are statistically significant, as well as the Partial Eta Squared value to determine the extent of the contribution or effectiveness of the treatment on the dependent variable.

In the fifth stage of qualitative data collection, the researcher conducted in-depth interviews with teachers and 5 students (2 high-ability students, 1 medium-ability student, and 2 low-ability students). The interviews aimed to detail and deepen their views, understanding, and experiences of the teaching materials or media that had been developed.

In addition, researchers distributed questionnaires to students to obtain responses or feedback on the media/ teaching materials that had been developed. The questionnaires were compiled with structured questions to provide a stronger basis for understanding perceptions, levels of satisfaction, and constructive suggestions related to the learning materials that had been prepared. The combined approach of interviews and questionnaires is expected to provide a more comprehensive and in-depth picture of the practicality of learning media. Student responses to interactive android-based learning multimedia as in Table 6 and categories of practicality android-based interactive learning multimedia as in Table 7.

Table 6. Student response grid for learning multimedia interactive android-based

Aspects/Materials/Indicators	Number
Interest	6
Material	6
Language	3

$$\text{Percentage} = \frac{\text{Score}}{\text{Maximum score}} \times 100\ \% \quad (4)$$

Table 7. Categories of practicality of learning multimedia interactive android based

Level of achievement	Category
81 – 100	Very good
61 – 80	Good
41 – 60	Enough

In the next stage, the researcher interprets the data, namely the interpretation of quantitative and qualitative data. Quantitative data such as pre-test and post-test data used to see a significant increase in the understanding and application of Computational Thinking (CT) in the group of students who were given treatment, namely by using STEM-integrated interactive learning multimedia. In addition, through statistical analysis, a significant relationship can be found between STEM-integrated interactive learning multimedia and increased Computational Thinking skills student.

Qualitative data such as in-depth interviews with students and teachers can be used. to explore a deeper understanding of how interactive learning multimedia influences the learning process. By using integrated interactive STEM learning multimedia, it can help students understand the science concepts of heat material better, and can increase student engagement during learning.

Result and Discussion

Figure 3. Home menu on android-based interactive learning multimedia

The result of this development research is an interactive multimedia learning product based on STEM STEM-integrated Android to improve students' computational thinking skills. The result of this product is in .exe format that can be run on a computer or laptop and in .apk format in the form of an Android application that can be installed on a smartphone. This product consists of several parts such as the initial display of the application, home menu, introduction menu, CP and TP menu, material menu, video menu, LKPD menu, Augmented Reality menu, STEM menu, practice question menu, online question menu, reference menu, and developer menu.

After the product development stage is carried out, the next step is to test the validity of the material and media for lecturers and teachers. The results of expert validation on the suitability of the material and media for developing interactive learning multimedia based on Android integrated with STEM are presented in the following table.

Table 8. Table of results of material expert validation test

Aspect	Validator 1	Validator 2	Validator 3	Average
Grammar	12	12	12	12
Main Material	34	35	36	35
Supporting Materials	10	10	11	10
Worksheet	12	11	11	11
Augmented Reality	10	10	12	11
Question	11	12	11	11
Amount	89	90	93	91
Validation percentage (%)	93	94	97	94
Criteria	Very valid	Very valid	Very valid	Very valid

Based on the results of the validation test obtained, the percentage of validity by validator 1 is 93%, interactive learning multimedia is very valid, the percentage of validity by validator 2 is 94%, interactive learning multimedia is very valid, the percentage of validity by validator 3 is 97%, interactive learning multimedia is very valid. The average percentage of validity is 94% so that interactive learning multimedia based on Android integrated with STEM is very valid for use in learning.

Table 9. Media expert validation test results table

ASPECT	Validator 1	Validator 2	Validator 3	Average
Android application view	12	12	12	12
Main Material	15	16	16	16
Supporting Materials	10	10	10	10
Worksheet	7	7	8	7
Augmented Reality	8	8	8	8
Question	8	8	8	8
Amount	60	61	62	61
Validation Percentage (%)	94	95	97	95
Criteria	Very valid	Very valid	Very valid	Very valid

Based on the results of the validation test obtained, the percentage of validity by validator 1 is 94%, interactive learning multimedia is very feasible, the percentage of validity by validator 2 is 95%, interactive learning multimedia is very valid, the percentage of validity by validator 3 is 97%, interactive learning multimedia is very valid. The average percentage of validity is 95% so that interactive learning multimedia based on Android integrated with STEM is very valid for use in learning.

This STEM-integrated android-based interactive learning multimedia was developed by holding the principle of cognitive theory of multimedia learning that the human information processing system can occur through two things, namely visual and verbal. The use of technology in the developed learning media helps educators in displaying various visual forms that can support learning. Dale (1969) emphasized the need to expand students' learning experiences through the use of audiovisual media, thus providing a strong foundation for deep and sustainable understanding. This android-based interactive learning multimedia application was developed by considering the characteristics of the material and the characteristics of the learning media so that it is equipped with the use of audiovisual elements.

Multimedia also has an Augmented Reality (AR) menu. Augmented Reality (AR) is a technology that combines the real world with digital elements interactively and in real-time (Wahyuni, 2021; Hernanda & Aji, 2024; Kafilahudin & Akbar, 2024; Usmaedi et al., 2020). With AR, digital elements such as images, sounds, animations, or other data are projected into the real world through devices such as smartphones, so that users can interact with the combination of the real and digital worlds. During implementation in the classroom, the level of learning implementation is measured using an observation sheet that refers to the implementation of learning with the RPP or teaching modules that have been prepared. The results of learning implementation can be seen in the following table.

Table 10. Learning implementation

Observer	Implementation Rate (%) Learning to-			Average (%)	Criteria
	1	2	3		
Science Teacher	93.42	94.44	95.83	94.57	Very high

Based on the table of learning implementation level, it can be seen that the implementation of learning showed very good results with an average implementation level of 94.57%, which is included in the "Very High" criteria. There was an increase in each meeting, starting from the first learning with an implementation level of 93.42%, increasing to 94.44% in the second learning, and reaching 95.83% in the third learning. This increase shows the consistency and effectiveness of the implementation of the learning carried out.

Student response data is used to obtain data on the practicality of Android-based interactive learning multimedia.

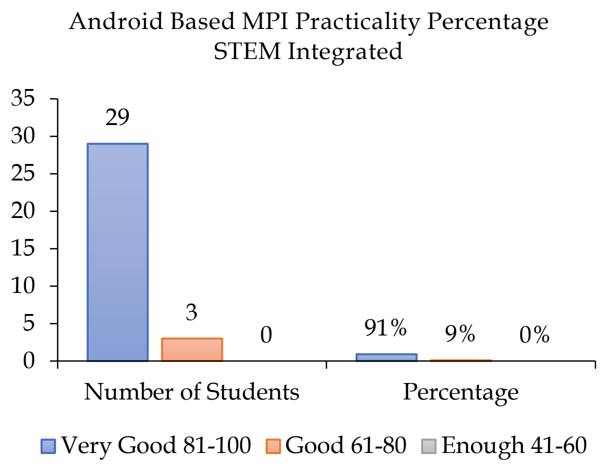

Figure 4. Practicality of android-based interactive learning multimedia

Based on the data above, 29 students (91%) responded to the STEM-integrated Android-based MPI with very good scores, 3 students (9%) responded to the STEM-integrated Android-based MPI with good scores, overall the STEM-integrated Android-based MPI can be said to be very practical to use in learning.

The learning experience using an interactive learning multimedia application based on STEM-integrated Android has an impact on changes in students' computational thinking abilities. The use of this interactive learning multimedia application based on STEM-integrated Android that has been developed can be said to be effective in improving students' computational thinking based on the results of the product effectiveness test. The increase in students' computational thinking abilities is seen based on the pretest and posttest scores of students in the experimental and control classes.

Table 11. N-Gain test

Class Group	Pretest Average	Posttest average	Average N-Gain	Category
Experiment	51.47	88.28	0.77	Tall
Control	52.38	60.625	0.17	Low

Based on the data above, the average percentage of N-Gain scores in the experimental class is 0.77 with a high category. The average percentage of N-Gain scores in the control class is 0.17 with a low category. The average N-Gain value for the experimental class is greater than the control class, this shows that the computational thinking ability in the experimental class after using the problem-based learning model and interactive learning multimedia integrated with STEM is greater than the control class using conventional learning (lectures) and the media used is PPT. From these results, it can be concluded that problem-based learning using interactive learning multimedia integrated with STEM is effective in improving students' computational thinking.

Table 12. ANCOVA impact test

Tests of Between-Subjects Effects						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18261.827[a]	2	9130.913	309.281	0.00	0.91

Dependent Variable: Posttest Value

Based on the table above, look at the significance value class indicator (Sig.) = 0.00 The sig. value < 0.05, this indicates a significant difference between the experimental class and the control class. The experimental class variable has a strong influence on the posttest value with a Partial Eta Squared of 91%.

Students in both the experimental and control classes were trained in problem-solving during the learning process by working on questions with computational thinking indicators, which include Decomposition, Pattern Recognition, Abstraction, and Algorithms. The approach applied to train students' problem-solving skills was the computational thinking approach (Dewi et al., 2021; Maulina et al., 2021; Yuntawati et al., 2021). The questions and answers based on computational thinking indicators can be seen in the following image.

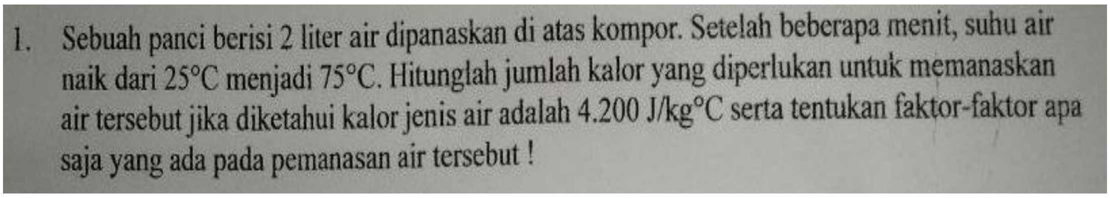
1. Sebuah panci berisi 2 liter air dipanaskan di atas kompor. Setelah beberapa menit, suhu air naik dari 25°C menjadi 75°C. Hitunglah jumlah kalor yang diperlukan untuk memanaskan air tersebut jika diketahui kalor jenis air adalah 4.200 J/kg°C serta tentukan faktor-faktor apa saja yang ada pada pemanasan air tersebut !

Figure 5. Questions with computational thinking abilities

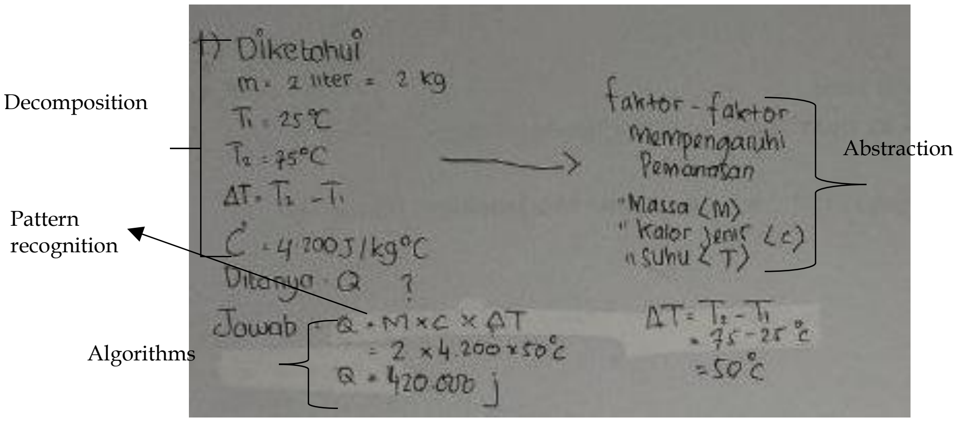

Figure 6. Student answers

The student's answer above shows a good application of the Computational Thinking (CT) concept in solving heat problems. All indicators of Computational Thinking are present. The student's answer can be analyzed using the Computational Thinking (CT) concept. In the Decomposition stage, students break down the problem into small parts, such as recording known data (mass, initial temperature, final temperature, and specific heat) and determining what is being asked (heat). Furthermore, in Pattern Recognition, students recognize the pattern of heat calculations using the formula Q = m × c × ΔT. This stage includes calculating temperature changes ($\Delta T = T_2 - T_1$). In Algorithms, students follow systematic steps, namely calculating Δ T, entering values into the formula, and completing the calculation until obtaining the result Q = 420,000 J. Finally, in the Abstraction stage, students demonstrate abstract understanding by identifying factors that affect heating, such as mass, specific heat, and temperature changes. Thus, students successfully apply the concept of Computational Thinking in a structured manner to solve physics problems about heat.

Conclusion

Based on the research results on the development of interactive learning multimedia based on Android integrated with STEM, the following conclusions can be drawn, namely: This STEM-integrated android-based interactive learning multimedia product is an android application in apk format that can be installed on a smartphone. The STEM-integrated android-based interactive learning multimedia application consists of several menus, namely the home menu, introduction menu, CP and TP menu, material menu, video menu, LKPD menu, Augmented Reality (AR) menu, STEM menu, practice question menu, online question menu, reference menu, and developer menu. This STEM-integrated android-based interactive learning multimedia application is very valid so that it is suitable for use in learning. This is based on the results of the validation test obtained, the average percentage of validity by material experts is 94%, the average percentage of validity by media experts is 95%; The interactive learning multimedia application based on Android integrated with STEM is very practical to use in learning based on the results of student responses to the Android application. 29 students (91%) responded to the interactive learning multimedia based on Android with a very good score, 3 students (9%) responded to the interactive learning multimedia based on Android integrated with STEM with a good score, with a very high level of learning implementation, namely (94.57%); This interactive learning multimedia application is effective in improving computational thinking skills, which can be seen from the effect size calculation with a value of 91%. shows that this Android-based interactive learning multimedia has a big influence in improving students' computational thinking skills, and based on the pre-test and post-test results, the average N-Gain score was 0.77 with a high category.

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Author Contributions
S.F. contributed to the instrument creation, interactive learning multimedia creation, data collection, and article writing; A. contributed as a supervisor in article writing and as a corresponding author; A.S. contributed as a supervisor in interactive learning multimedia creation, research data analysis, and article writing; D.L. contributed as a supervisor in instrument creation and article writing.

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The authors declare no conflict of interest.

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