

Use of a physics calculator with Matlab as a teaching tool for the idea of thermodynamics

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Abstract: Many physics equations in the thermodynamics content cause pupils to become abstract in their grasp of the subject. To be able to visualise the thermodynamics material, one needs a learning tool. Usually, numerical analysis uses Matlab. Students can currently utilise Matlab to learn physics in order to fully comprehend the subject. The goal of this study is to use Matlab software to create a physics calculator application on the topic of thermodynamics. The research development method with the ADDIE development model was the research methodology employed in this study (Analysis, Design, Development, Implementation and Evaluation). A validation test questionnaire and a student response questionnaire were the tools employed in this investigation. The descriptive analysis and average analysis are the methods of analysis used.

Keywords: Physics Calculator, MATLAB, Thermodynamics

Introduction

The development of science and technology is based on the underlying science of physics (Malik et al., 2017). Given the significance of physics, students should have a solid understanding of it. All educational levels, including elementary, secondary, and higher school, can study physics. By employing physics concepts and principles to explain a variety of natural events and solve issues both qualitatively and quantitatively, physics courses serve to improve inductive and deductive analytical thinking skills (Bain et al., 2014; Liliarti & Kuswanto, 2018). The science of heat and transfer is referred to as thermodynamics (Ratnaningtyas et al., 2019). Several ideas that are relevant to daily living and the usage of technology are found in the concept of thermodynamics. Thermodynamics is a part of physics that studies heat, work, temperature and energy. Students have to master every thermodynamic material delivered by the teacher because it is one of the materials that will be included in the national exam. But in reality, in thermodynamics material, many students experience misconceptions, so that it will impact errors in answering thermodynamic equations. Based on an interview, one of the physics teachers at a high school in Jakarta explained that many student test scores had not yet reached the minimum completeness criteria (KKM). Of the 36 students, it was found that only 20% of students got physics scores above the KKM, while 80% of them got lower than the KKM. In addition, students are also not used to deriving thermodynamic equations, so when they face thermodynamic problems, they experience problems in implementing physics equations into questions in the form of stories. Most students consider physics lessons to be the most difficult and scary subjects. The main contributing factor is the presence of so many formulas in physics that the purpose of physics, which is a study to explain the processes of natural phenomena that occur, is not easy to understand. Students consider these formulas to be memorized, even though the formulas are actually the consequence of simplifying statements of phenomena and processes that occur in nature and can help students' understanding in learning physics. Students' difficulty in studying physics is caused by two factors: the density of physics material with a lot of calculating and classroom physics learning, which is not contextual and seems abstract. The use of media in the physics learning process will greatly assist students in understanding abstract physics concepts (Nursulistiyo, 2018).

Therefore, we need learning media in the form of aids for students in understanding the material being studied and developing students' thinking levels. With learning media, students are more interested in taking physics lessons than explaining physics material only by lecturing or presenting with powerpoints (Astra et al., 2015; Oktavianingtyas et al., 2018). Learning media that can be used to visualize abstract physics concepts in thermodynamics uses a Matlab-based physics calculator application.

Matlab is software used for numerical analysis, linear algebra, and matrix theory (Hong & Cai, 2010; Kim, 2017). Matlab can be viewed as a full-featured calculator. An ordinary calculator only has

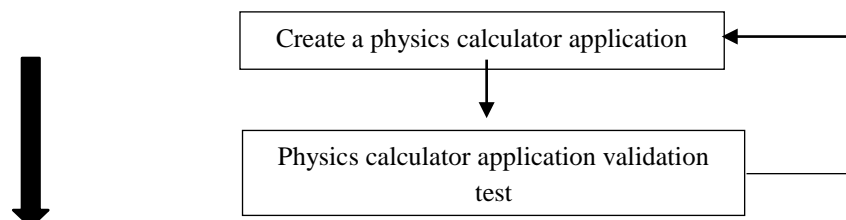
basic facilities; for example, there are only facilities for addition, subtraction, multiplication and division. A complete calculator is called a scientific calculator with the facilities provided not only as mentioned above, but also trigonometric functions, complex numbers, square roots and logarithms (Tang et al., 2010). Usually, the Matlab application is used to explain the visualization of physics material in the form of a sinusoidal image and includes a calculator for calculating physics formulas (Parinduri, 2018). Many have developed physics calculator applications, such as Joshua's research in making physics calculators on GLB and GLBB materials (Yosua et al., 2020). In addition, several studies have created physics calculators on the concepts of physical quantities, work, and energy (Sumarni et al., 2021). The research that has been done only displays a physics calculator and has not yet been applied to practice physics questions so that when understanding physics, students seem to memorize it. The application of the Matlab application can be used to create a Graphic User Interface (GUI) to analyze physics experiments or physics concepts (Nurullaeli & Astuti, 2018). Matlab-based physics calculator can be used by displaying many features in Matlab.

The purpose of this research is to develop a Matlab-based calculator application as a medium for learning physics. With the Matlab-based physics calculator application created, students will find it easier to understand physics concepts. Apart from displaying physics formulas, physics calculators can also be used to prove a physics problem. The application also displays physics concepts in brief, plus a video explanation of physics material to learn physics independently.

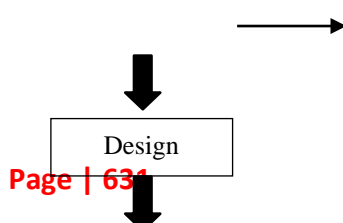
Method

The research method used in this research is the research and development method, with the development model of ADDIE (Analyze, Design, Development, Implementation, Evaluation) (Rayanto & Sugianti, 2020). The following are the stages of implementation in making the physics calculator application shown in Figure 1.

Figure 1 shows the process of developing a physics calculator application based on the ADDIE model. The steps in developing the ADDIE model are: (1) Analyze. This analysis stage is the stage of



looking for information in the field or needs analysis by identifying problems that can serve as the purpose of the need to develop a physics calculator; (2) Design. This stage is carried out by designing and designing the physics calculator application being made, which includes making the design, making the framework for the contents of the physics calculator application, and completing the physics material and the exercises that will be displayed; (3) Development. This stage is the stage of making a physics calculator application. After the Matlab-based physics calculator application is manufactured, the product is tested for validity to determine the feasibility of the learning media. Material experts and media experts carry out the validation test. The next thing to do is to revise the physics calculator application according to the advice of the experts. Revisions are made to improve products that have been made and improve products developed before the product is tested on students; (4) Implementation. At the implementation stage, small class trials were carried out on students to see the impact and responses of students to the physics calculator application; (5) Evaluation. At this stage, an evaluation of the physics calculator application has been developed based on student responses and validation results from experts.



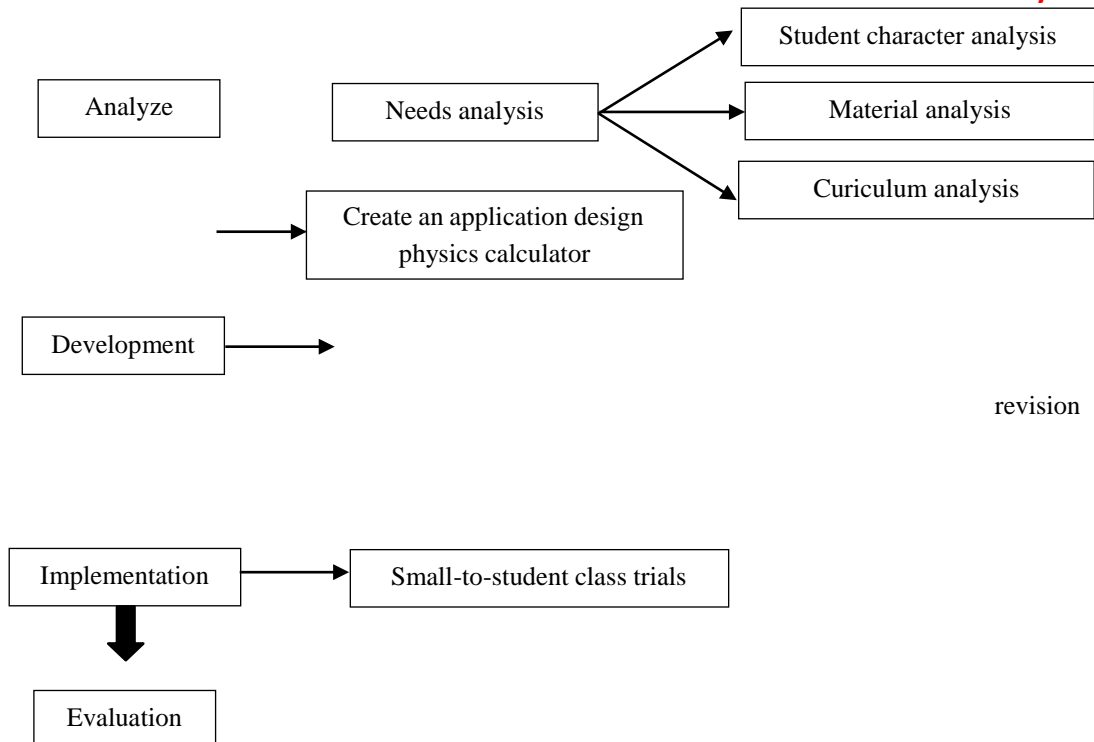


Figure 1. ADDIE development model flowchart

The research instrument that will be used in this research is a validation questionnaire that will be given to the experts, plus the student response sheets. The instrument used in this study was a questionnaire containing response questions using a Likert scale. The data analysis technique used is the average value of each validation. The results of student responses to the physics calculator application are also seen on average to see whether students respond positively or not. The validation data analyzed is then processed so that it can be read in the form of structured information and presented in the form of a percentage to see whether the physics calculator application has met the appropriate criteria or not, according to the feasibility table of learning media shown in Table 1.

Table 1. Eligibility criteria for instructional media

Achievement Level	Qualification
90 % - 100%	Very Good
75 % - 89%	Good
65 % - 74 %	Moderate
55 % - 64 %	Low
0 % - 54 %	Very Low

Results and Discussion

The product produced in this study is a learning media for a Matlab-based physics calculator. This application is designed as an ordinary calculator and as a learning medium because it contains thermodynamic material. There are thermodynamic exercises so that students can better understand the material. In the material of thermodynamics, there are three sub-materials displayed in the physics calculator application, namely: First Law of Thermodynamics, Second Law of Thermodynamics, and Third Law of Thermodynamics, as seen in Figure 2.

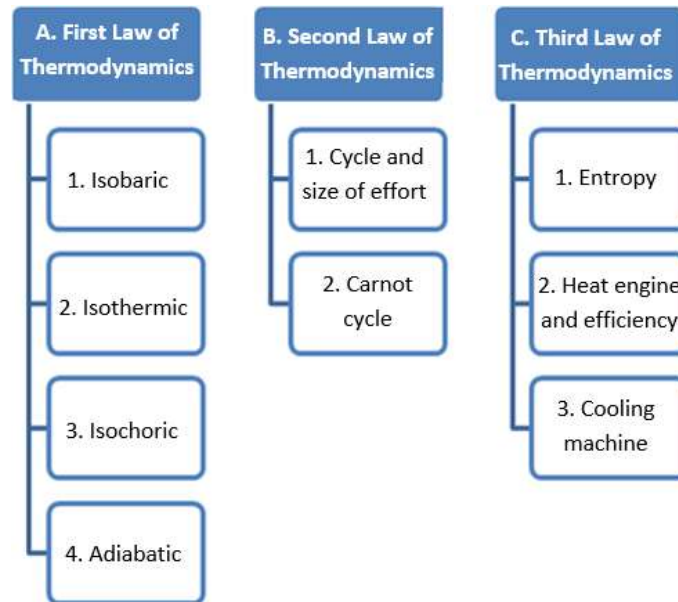


Figure 2. The design and arrangement of the material displayed on the physics calculator application

After creating a design or content framework for the Matlab application, the next step is to create a Matlab-based physics calculator application using a Graphic User Interface (GUI). Matlab GUI is one of the features in Matlab that can display the program being created visually. Matlab GUI is a solution to facilitate media creation. There are various kinds of graphic components in this programming application, namely Pushbutton, Toggle button, Radio Button, Edit Text and Static Text, Frame, Pop Up Menu and Axes. These components are designed into a figure that is needed in making a physics calculator application.

This physics calculator application is divided into several display parts: the home page view, the material view, the physics calculator display, and the physics exercise view. The physics calculator start screen contains start and exit buttons. To run this learning media, users can select the start button, as seen in Figure 3.



Figure 3. The start view of the physics calculator application

In the thermodynamic material section in this application, there are several more sub-materials in accordance with the concept of thermodynamics, namely containing the First Law of Thermodynamics, the Second Law of Thermodynamics, and the Thermodynamic Cycle. The sub-material is also divided into several more materials, as shown in the thermodynamic material menu display in Figure 4.



Figure 4. Material menu display of Physics calculator application

There are a short material, a physics formula, and a physics calculator in each thermodynamic material displayed. The presented calculator is proof of the thermodynamic formula to be applied to an exercise problem so that students can work on and match directly whether the answer is correct or not. So, each sub-material menu contains the concept of thermodynamics, thermodynamic formula, sample questions, and a physics calculator, as shown in Figure 5.

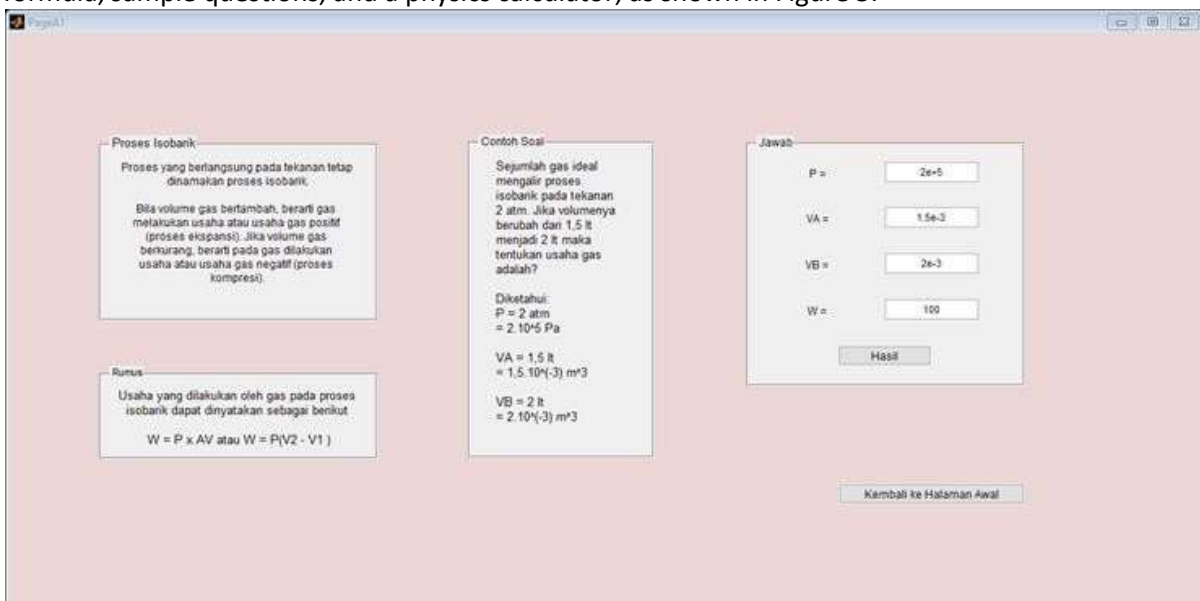


Figure 5. Display of physics calculator on the isobaric process material menu

In visualizing thermodynamic material, some pictures and illustrations can explain thermodynamic concepts that are considered abstract by students. When the image in the material menu is tapped, an illustration will appear, including explaining the material presented in the animation. In Figure 6, there is a picture of the flow of the cooling engine which will launch a visualization of the flow of the cooling engine working when the user taps the picture.

After the Matlab-based physics calculator application has been completed, the experts carried out an assessment or validation test. Material experts and media experts carry out the validation test. From the material validation test results, the minimum value obtained based on the expert's questionnaire was 80% with a good interpretation, and the maximum value obtained was 93.33%

with a very good interpretation. If average, the value obtained is 85.19%, which means that the material contained in this application, according to experts, is good and worthy of being tested in school.

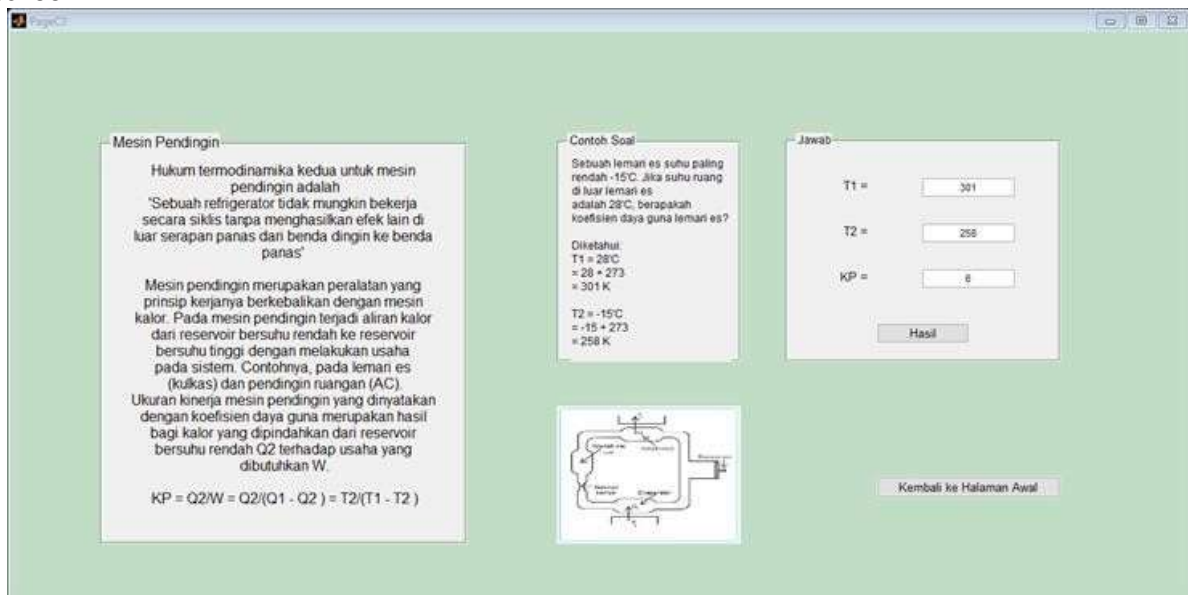


Figure 6. Display on Cooling Machine Material

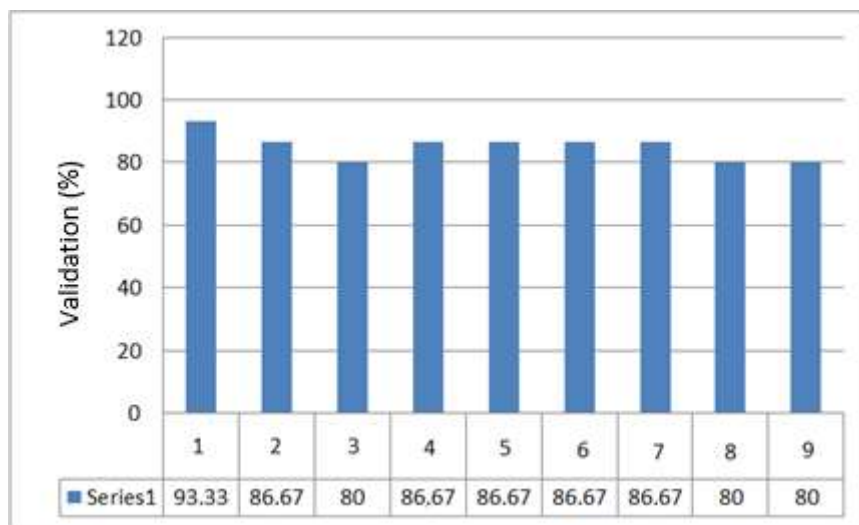


Figure 7. The results of the validation test by material experts

On the other hand, the validation test results by media experts show that the minimum value obtained based on the expert's questionnaire is 80% with a good interpretation, and the maximum value obtained is 90% with a very good interpretation. On average, the value obtained is 81%, which means that this media, according to experts, is good and worthy of being tested in school.

After validating the physics calculator application by media and material experts, the average validation value was 83.1%. Based on the feasibility category, the physics calculator application is in a good category and is feasible for students after being revised according to experts' suggestions. Some suggestions from experts are: (1) Avoid too much text in the material displayed, (2) Add thermodynamic evaluation questions, and (3) Adjust the size of the display buttons. After the revision was made, the physics calculator was then implemented and tested on students in small classes.

Based on student responses, an average value of 79.8% was obtained in the category of positive response to the physics calculator application. Students feel happy and interested in learning physics using the physics calculator application because it is different from other learning media.

Students can experiment with their physics calculator to prove whether the physics problems they are working on have the same results or not. Some of the responses from students include: (1) With the physics calculator application students are increasingly enthusiastic about learning thermodynamic material, (2) Students understand thermodynamic material which is abstract because of illustrations and simulations of thermodynamic concepts, (3) Students understand thermodynamic equations well so that they do not just memorize it, but they also learn the flow of thermodynamic equations.

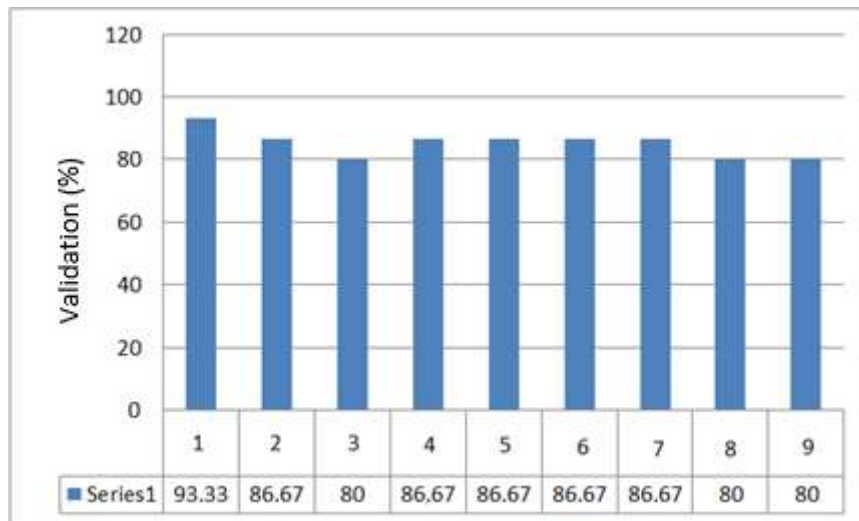


Figure 8. The results of the validation test by media experts

The Matlab-based Physics Calculator application is suitable to be used as a support for learning physics in thermodynamics material. Matlab can also be used as a physics calculator to help analyze physics experiments (Nugraha, 2020). Hutagalung also added the Matlab program with the Simulink method, where basic theory can be simulated into a display form in understanding electrical circuits (Hutagalung, 2018). The use of Matlab can also improve my understanding of physics material. In addition, Matlab can also be used to solve physics problems both in physics equations and in physics concepts (Notaroš et al., 2019).

The Matlab application empowers teachers and students with graphical visualization of how experimental and theoretical data interact and makes teachers and students not bother using laboratory equipment which is rarely available, because it can be displayed in virtual simulations with Matlab (Momox & De Maio, 2020). The Matlab application also supports blended learning to study independently with Matlab, and students still can discuss physics material with the teacher in the class (Talbert, 2013). Learning physics with Matlab cannot only be done face-to-face but can also be implemented in online learning. When students learn independently, the teacher acts as a facilitator by explaining how to use the physics calculator application, thus supporting student-centred learning.

Matlab, which is usually used as a calculation tool, can now also be used as a simulation learning medium. Matlab can display graphs, text material, practice questions, and a physics calculator. Matlab can be used as a physics learning medium to display the physics concept simulation process (Mushtaq et al., 2014; Sumarni et al., 2021). This is in line with the opinion that learning media has an important influence on the classroom's learning process (Rahmelina et al., 2019; Stathopoulou et al., 2019). Most students are very interested in learning physics using innovative learning media (Astuti et al., 2018; Muqarrobun & Kuswanto, 2016). The use of Matlab and physics can also be used as a medium for learning mathematics in various fields. For example, Matlab GUI can be used by class XI high school students to help understand trigonometric problems (Mulyawati et al., 2017). In line with Zulmi's research, the development of Matlab-based physics formulas can increase student motivation because they are interested in new and innovative learning media. In addition, the Matlab application can also be used to improve logic skills (Zulmi et al., 2018), students' ability to solve problems,

and students' communication skills (Kartika, 2014). Students memorise formulas and expect physics formulas with the help of Matlab in answering or providing solutions to physics problems that are being faced (Sabaryati & Zulkarnain, 2019).

There are many Matlab programs that can be made in physics materials, such as the concept of motion, heat temperature, thermodynamics, electricity, and so on. Simulations on Newton's Law of motion can also be displayed in the Matlab (Mansouri & Reinbolt, 2012). So not only standard calculators or physics calculators that can be displayed in Matlab, but they can also display graphs and physics simulations. Physics models and simulations made with Matlab are very interesting, and students can experiment on their own by adding features or buttons and filling in the values of existing physics quantities (Osaci, 2012; Setyansah & Apriandi, 2019). Matlab-based physics calculator learning media can also be implemented in learning physics in the classroom and combined with a learning model that is in accordance with the student's condition (Gil, 2017).

The Matlab-based physics calculator can be used as an innovative physics learning media for independent learning. This Matlab-based physics calculator has several advantages: (1) Displaying thermodynamic material; (2) Has a warning box (report) if the user fills in an incorrect value and has to correct it to proceed to the next step; (3) Has a physics calculator button or box that can be used when there is a physics practice problem (4) Has a physics equation that is displayed with a simulation (5) Has a thermodynamic question exercise to determine the student's ability to understand thermodynamic material, and (5) Can be used classics in class or independently without the need to be accompanied by a teacher on an ongoing basis.

Conclusion

Based on the results of research and discussion, it can be concluded that the learning media in the form of a Matlab-based Physics Calculator application on this thermodynamic material gets an average validation score of 85.19% by material experts and 81% by media experts. According to the experts, the average score by material experts and media experts is 83.1% in the "Good" category; in other words, according to the experts, this media is suitable for use in physics learning. This application also received a positive response from students with an average score of 79.8%. The physics calculator application can be used as a learning medium and a student aid in calculating and proving thermodynamic problems. The solutions to thermodynamic problems can be answered, and students can understand thermodynamic equations coherently, so they are not just memorizing physics equations but understanding these equations from the start to applying them to thermodynamic problems. The physics calculator application can also be used as a complement to student teaching materials to study independently.

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