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Development of a Simple Stirling Engine Demonstration Tool on the Subject of Thermodynamics

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ABSTRACT

Purpose of the study: The aim of this research is to develop a simple Stirling engine teaching aid for the class XI thermodynamics subject at high school and determine students' responses to the teaching aid developed.

Methodology: The research method used is research and development (R&D) ADDIE model, namely with the stages of analysis, design, development, implementation, evaluation. The instruments used in this research were media expert validation questionnaires, material expert validation, small group trials and field trials with a Likert scale. The data obtained was then analyzed quantitatively and qualitatively. The test subjects in this research were carried out using small group trials of 10 students and field trials of 30 students from three schools.

Main Findings: Based on the results of the material expert validation analysis and media expert validation, an average of 86.5% was obtained which could be categorized as very good, then for small group trials it was obtained 91.9% and 93.1% of field trials could be categorized as very good, so that the media for simple Stirling engine teaching aids were has been developed as a whole very well to be used as a teaching aid in learning in class XI High School.

Novelty/Originality of this study: The novelty of developing a simple Stirling engine demonstration tool for the study of thermodynamics lies in its innovative approach to making a complex subject accessible, engaging, and applicable to a wide range of learners, thereby fostering a deeper understanding and appreciation of the field.

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1. INTRODUCTION

Education is a very important part of human life, because with education we can become human beings who can benefit society and even the whole world [1], [2]. The definition of education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble morals, and the skills needed by themselves, society, nation and state [3], [4].

Learning is a directed process of interaction between teachers and students where in this process there is a transfer of knowledge from teacher to student in achieving learning goals [5]. Learning is a teaching and

learning process that involves students and educators using media [6], [7]. One of the lessons taught at every school level is science or natural science learning.

Natural science learning is closely related to the environment and the natural world. Natural science does not only consist of a collection of memorized knowledge or facts, but is an active activity or process of using the mind to study the secrets of natural phenomena. does not only consist of a collection of memorized knowledge or facts, but is an active activity or process of using the mind to learn the secrets of natural phenomena [8]. The problem that often arises and is experienced by students in learning is misunderstanding when studying physics material [9].

Physics subjects are one of the subjects in the science family that can develop inductive and deductive analytical thinking skills in solving problems related to natural events, both qualitatively and quantitatively using mathematics, and can develop knowledge, skills and self-confident attitudes [10]. So that in physics learning the teacher will explain the formulas, give examples of their application in everyday life, and carry out practical work in the laboratory [11]. The success of practical activities in physics learning is of course influenced by the availability of adequate practical equipment, including teaching aids [12].

The role and responsibilities of teachers cannot be replaced by advances in media no matter how great they are. In fact, this progress requires changes in the role of teachers to become increasingly broader [13]. If seen from its role, it means that the teacher is a source and also a facilitator who can create a fun learning process and make students more active, but in reality human knowledge is very limited so we need other sources of information both in learning and teaching other people. .

Teachers as transmitters of learning material not only deliver teaching materials that are in accordance with the design of the learning program, but teachers are also required to be able to use the tools that can be provided by the school, and do not rule out the possibility that these tools are in accordance with developments and demands of the times [14], [15]. Teachers can at least use cheap and efficient tools which, although simple and unpretentious, are a must in order to achieve the expected teaching goals. Apart from being able to use the available tools, teachers are also required to be able to develop skills in making learning media that they will use if the media is not yet available.

A problem that is easy to do, requires other components to support this. One component that can be used as media provided by the teacher is teaching aids. The role of teaching aids is very important as a tool to convey material, especially in physics material where the concept or material is difficult to understand and requires tools so that difficult learning material can be easily understood by students.

Physics is a branch of science that underlies technological developments and the concept of living in harmony with nature. Physics also provides good lessons for students to live based on natural laws. 6 The laws of physics are the result of human thought which has limitations, meaning that the laws of physics are not immune to change and the theories are certain [16]. Based on technological developments, the concept of natural law will not work optimally without a good understanding of physics. Teachers as facilitators should be able to utilize existing potential, the Stirling engine can be a good medium for demonstrating several basic physics concepts.

As an example of an external combustion engine application, this tool has a working principle that can explain the concepts and laws of thermodynamics. Then, based on the results of previous research, it was found that the KIT stirling engine is suitable for use as a physics learning medium in thermodynamics material by fulfilling aspects of validity, student learning outcomes, learning implementation, and student responses [17]. The difference between previous and current research lies in the sample and research time. So the results of this research can be a generalization of previous research.

Based on students' needs and supported by the increasing demand for fuel and the need for alternative energy sources that are environmentally friendly and easy to obtain which are currently available, the introduction of alternative energy sources for high school students can be an appropriate learning reference. Then another urgency for carrying out this research is that educators can bridge the gap between theory and practice in thermodynamics learning, thereby cultivating a generation of learners who are equipped with a deeper understanding of this fundamental scientific field. The novelty of developing a simple Stirling engine demonstration tool for the study of thermodynamics lies in its innovative approach to making a complex subject accessible, engaging, and applicable to a wide range of learners, thereby fostering a deeper understanding and appreciation of the field. Through these considerations, it is necessary to develop a simple mixing machine teaching aid for the class XI high school thermodynamics subject.

2. RESEARCH METHOD

This research uses a qualitative and quantitative approach, this is based on the formulations that emerged in this research which requires researchers to carry out exploration in order to understand and explain the problems that are the focus of this research problem, then collect various data and information through observation , distribution of questionnaires and documentation studies of the required data sources. The research

location is SMA AL-Azhar 3 Bandar Lampung, SMA Gajah Mada Bandar Lampung, and MA Al-Hikmah Bandar Lampung.

The method used is Research and Development, which is a research method used to conduct research in an effort to develop existing products (innovation) or to create new, tested products (creation). The purpose of this research and development method is to use to produce certain products in order to test the effectiveness of the product so that it functions in the wider community, so research is needed to test the effectiveness of the product. 2 This research and development is based on existing research, namely the Stirling engine which was then developed to be simpler to use. as a teaching aid for physics material on thermodynamics for class XI high school.

The development research procedure is guided by the research design for the development of instructional materials by Robert Maribe Branch with the ADDIE approach, which is an extension of Analysis, Design, Development, Implementation and Evaluation, research and product development procedures.At this development stage, products will be produced in the form of teaching aids based on the media design at the design stage. The finished teaching aids then go through validation tests by experts.

The validation test aims to determine the validity of the resulting teaching aids. Then the props will also be evaluated to see to what extent they can and are suitable for use. Through evaluation, the advantages and disadvantages of the tools will be known and it is possible to make improvements so that the learning media in the form of teaching aids will be good. After improvements or revisions have been made, then the teaching aids can be implemented. If possible, there will be another evaluation and revision until the media in the form of teaching aids becomes better.

The research instrument uses questionnaires and interviews. Data analysis in this research uses qualitative and quantitative descriptive analysis techniques. This qualitative descriptive analysis technique is used to process data from assessments on media expert validation, material expert validation, and product trials of simple Stirling engine teaching aids on students, namely small group trials carried out by 10 samples of students and field trials carried out by 30 samples. learners. Quantitative descriptive analysis is data that describes the results of media expert validation, material expert validation, product trials for developing simple Stirling engine teaching aids. The following is the media expert validation grid:

Table 1. Media expert validation grid

No.	Assessment Aspects	Indicator
1.	Product Design	Has a proportional shape
		Easy to assemble
		Attractive color
		Materials are easy to get
		Safe material to use
		Materials that are economically valuable or relatively cheap
		Practical or easy to carry
2.	Language	Daily use of sentences
		Use of spelling clearly
		Correct Use of Sentences
		Correct Use of Terms
		Consistency in the Use of Terms, Symbols, Scientific Names/Foreign Languages
3.	Serving	Feasibility of teaching aids to be tested
		The effectiveness of teaching aid media

Furthermore, the material expert validation grid is as follows:

Table 2. Material expert validation grid

No.	Assessment Aspects	Indicator
1.	Content Eligibility	Suitability of examples to the material
		Suitability of media to indicators
		Suitability of the media to the material
2.	Language	Concept Truth
		Accuracy of Facts
		Easy to understand material
		Can present physics concepts
		In accordance with physics concepts
		Can demonstrate physics concepts clearly

3. RESULTS AND DISCUSSION

Research and development of simple Stirling Engine teaching aid media on the subject of Thermodynamics class Al-Hikmah Bandar Lampung. This simple Stirling engine teaching aid was created to make it easier for students to understand physics subjects, namely the material on the 1st law of thermodynamics on the efficiency of Carnot engines, thermodynamic processes and heat engines, where this material is material that is quite difficult for students to understand if it is only explained. using the lecture method by the teacher. The limited teaching aids available in schools are a challenge for teachers in developing potential that is easily available in the environment, so simple teaching aids are needed that can make it easier for teachers to convey the material and for students to understand the material presented.

The development of this simple Stirling engine teaching aid began with a literature study by looking at the material in the literature supported by survey results from 3 schools, namely interviews with teachers, then distributing questionnaires to students who really needed simple teaching aids for thermodynamics material, then the researchers were interested in developing the tool. Demonstrate a simple Stirling engine to explain the laws of thermodynamics. This simple Stirling engine prop is made from materials that are no longer used and is designed so that it can be used to demonstrate the Stirling engine from the concept of the 1st law of thermodynamics. The Stirling engine is a closed cycle heat exchanger that utilizes external combustion as a source of heat energy. This utilizes the concept that air can expand when heated and will contract when cooled, so that when the engine is heated the air volume increases and the pressure increases, then converts heat energy into mechanical motion that can move the wheels. The following is a sketch of the initial drawing for making a simple Stirling engine prop:

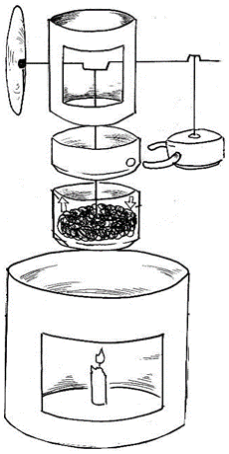

Figure 1. Initial sketch of the Stirling engine

The following is a picture of the resulting Stirling engine

Figure 2. Final result of a simple sterling machine product

The next stage was a validation test carried out by 3 media expert lecturers to assess product design, language and presentation, 3 material expert lecturers assessed the suitability of the content and suitability of the concept in the media of simple Stirling engine teaching aids and LKS. The following are the results of the validity assessment from media experts after several improvements..

Table 1. Validity assessment results from media experts

Assessment Aspects	Assessment Indicators	Evaluator 1	Evaluator 2	Evaluator 3	$\sum$ per aspect	Average per aspect	Ideal Percentage (%)
Product Design	1	5	5	4	95	4.5	90.5
	2	5	5	5			
	3	5	4	4			
	4	4	4	5			
	5	5	4	4			
	6	4	4	5			
	7	5	5	4			
Language	8	4	4	4	65	4.3	86.7
	9	5	4	5			
	10	5	5	4			
	11	4	4	4			
	12	4	4	5			
Presentation	13	5	5	5	30	5.0	100
	14	5	5	5			
Total		65	62	63	190	14	277.1
Mean		4.6	4.4	4.5	63.3	4.6	92.4
Information		VG	VG	VG		VG	VG

Based on table 1, namely assessor 1 (Chin Peng Ching), the average obtained was increased to 4.6 and was interpreted with very good criteria. Assessor 2 (Mr. Adekunle Oyewo) the average obtained increased to 4.4 and was interpreted with very good criteria, assessor 3 (Mr. Antomi Saregar) the average obtained was the same as 4.5 because it was suitable for use without revision and interpreted with very good criteria. Good.

The table after validation improvements carried out by 3 media expert lecturers showed the results of the assessment of 3 assessment aspects as follows: in the product design assessment aspect of 7 assessment indicators, the total score obtained increased to 95 with the average being 4.5 and the ideal percentage being 90.5%. In the language assessment aspect with 5 assessment indicators, the total score increased to 65, the average score obtained became 4.3 and the ideal percentage became 86.7%. Then, in the presentation assessment aspect with 2 assessment indicators, the number of scores obtained increased to 30 and the average score became 5.0, the percentage of success obtained became 100%. So that the overall results of media expert validation can be interpreted with very good criteria. Based on the data from media expert validation results contained in the table, the percentage of 3 assessment aspects, namely product design, language and presentation, can be seen in the percentage diagram that the language assessment aspect has the lowest percentage, namely 86.7%, which can be interpreted with very good criteria. The product design got higher results, namely 90.5% which could be interpreted with very good criteria, and the presentation assessment aspect had the highest percentage, namely 100% which could be interpreted as very good. Material expert validation was carried out by 3 expert lecturers from UIN Raden Intan Lampung, namely assessor 1 by Mrs. Sri Latifah, assessor 2 by Mr. Ardian Asyhari, and assessor 3 by Mr. Antomi Saregar. The validation stage is carried out by filling out a questionnaire which includes 2 aspects of assessment, namely the suitability of the content and the suitability of the concept. The validation questionnaire sheet uses a Likert scale with a rating range of very good to not good. The results of the expert material validation can be seen in the following table:

Table 2 Results of material expert assessment

Assessment Aspects	Assessment Indicators	Evaluator 1	Evaluator 2	Evaluator 3	$\sum$ per aspect	Average per aspect	Ideal Percentage (%)
Content Eligibility	1	4	4	4	35	3.9	77.8
	2	4	4	4			
	3	4	3	4			
Concept Suitability	4	5	4	5	75	4.2	83.3
	5	4	3	4			
	6	3	4	4			
	7	4	4	5			
	8	4	4	5			
	9	4	4	5			
Total		36	34	40	110	8.1	161.1
Mean		4	3.8	4.4		4.03	80.6
Information		G	G	VG		G	G

Based on table 2, namely the results of the assessment by material experts, appraiser 1 got an average of 4 and interpreted it with good criteria. Rater 2 got an average of 3.8 and interpreted it with good criteria. Rater 3 got an average of 4.4 and interpreted it with very good criteria. Good. The validation table carried out by 3 material expert lecturers obtained assessment results with 2 assessment aspects as follows: in the content feasibility assessment aspect of 3 assessment indicators, the total score obtained was 35 with the average being 3.9 and the ideal percentage being 77.8%, in this aspect assessing the suitability of the concept with 6 assessment indicators, the total score was 75, the average score obtained was 4.2 and the percentage of success was 83.3%. So that the overall results of media expert validation can be interpreted with good criteria. Based on data from media expert validation results contained in table 4.8, the percentage of 2 assessment aspects, namely content suitability and concept suitability, can be seen in the percentage diagram that the content suitability assessment aspect has the highest percentage, namely 85.7%, which can be interpreted with very good criteria. Concept suitability gets better results. low, namely 81.3% and can be interpreted with good criteria.

Based on the validation data obtained by media experts and material experts. The overall percentage of assessment aspects contained in media expert validation obtained higher results, namely 92.4% and could be interpreted very well so it was suitable to be tested on high school students, while for material expert validation the results were lower, namely 80.6% and could be interpreted well and suitable for use on students for testing

The simple Stirling engine teaching aid that has been developed and has gone through the validation stage by media experts can then be tested on students to see the students' responses regarding the aspect they want to know, namely the ease and response of students in using the simple Stirling engine teaching aid.

The trial phase was carried out twice, namely small group trials and field trials. The small group trial was carried out with 10 samples of students from three schools in Bandar Lampung, namely SMA AL-Azhar 3, SMA Gajah Mada, and MA Al-Hikmah. The results of students' responses in small group trials of the simple stirling engine teaching aids that were developed are in table 3 below:

Table 3. Results of small group trials

Assessment Aspects	Assessment Indicators	Evaluator	$\sum per\ aspect$	Average per aspect
Ease of using props	1 2 3	138	4.6	92
Student response	4 5 6 7 8 9 10 11 12	413	4.6	91.8
Total		551	9.2	183.8
Mean		275.5	4.6	91.9
Information			VG	VG

Based on table 3, namely the results of small group trials, assessments carried out by 10 students with 2 assessment aspects, in the assessment aspect of ease of using teaching aids, 3 assessment indicators, the total score obtained was 138 and obtained an average of 4.6. The success percentage obtained was 92%. Aspects of assessing student responses with 9 assessment indicators, the total score obtained was 413 with an average of 4.6, and a success percentage of 91.8%. So the overall assessment of the aspects obtained was 91.9% and can be interpreted with very good criteria.

The field trial was carried out with 30 samples of students from three schools in Bandar Lampung, namely SMA AL-Azhar 3, SMA Gajah Mada, and MA Al-Hikmah. The results of the students' responses to the field trials of the simple stirling engine teaching aids that were developed are in table 4 below:

Table 4. Field trial results

Assessment Aspects	Assessment Indicators	Evaluator	$\sum$ *per aspect*	Average per aspect
Ease of using props	1 2 3	414	4.6	92
Student response	4 5 6 7 8 9 10 11 12	1272	4.7	94.2
Total		1686	9.3	186.2
Mean		843	4.7	93.1
Information			VG	VG

Based on table 4, namely the results of the assessment field trials carried out by 30 students with 2 assessment aspects, in the assessment aspect of ease in using teaching aids, 3 assessment indicators, the total score obtained increased by 414 and the average remained at 4.6, the percentage of success obtained The result remains 92%. Aspects of assessing student responses for 9 assessment indicators, the total score obtained was 1272 with the average obtained increasing to 4.7, and the ideal percentage increasing by 94.2%. So the overall assessment of the aspects obtained increased by 93.1% and can be interpreted with very good criteria. Based on data from the results of small group trials and field trials contained in the table, the overall percentage of assessment aspects, namely ease of using teaching aids and student responses seen in the diagram, has a very good percentage, namely 91% and 93.1%.

The students' response when carrying out the trial stated that they were very interested in the Stirling engine teaching aids that had been developed, because the shape and appearance of this simple Stirling engine teaching aid was very attractive to students. Supported by this Stirling engine teaching aid, it was very easy to operate, so that students could easier and more motivated to learn the material presented. This Stirling engine teaching aid can provide a new experience in the learning process which is very enjoyable. Based on students' assessment responses to the teaching aids developed through questionnaires during small group trials and field trials after statistical testing, they can be categorized as very good.

The simple Stirling engine teaching aid has gone through the validation stage by media and material experts with suggestions for improvement to obtain feasibility results, so that the teaching aid is ready to be tested to get a very good response from students. Based on the results of trials from research and development as a whole, it can be categorized as very good, which can be seen in the data obtained from calculating all aspects of the assessment.

This research and development produced the final product in the form of a simple Stirling engine demonstration tool on the subject of thermodynamics which has advantages and disadvantages. The following are some of the advantages of a simple Stirling engine trainer:

1. Can explain interrelated thermodynamic material, namely the 1st law of thermodynamics, thermodynamic processes (isothermal, isobaric, isochoric, adiabatic), p-V diagrams, Carnot engine cycle and heat engines
2. Can be used as a teacher's tool in delivering difficult thermodynamics material that is easier for students to understand.
3. It is easy to practice because it is made from unused materials and is easy to find
4. It is very effective to use as learning motivation for high school students in developing physics so that it can be applied in everyday life so that in the future it can produce a creative and skilled young generation.
5. It is very easy to assemble because the ingredients are not dangerous if introduced to high school students.
6. The Stirling engine is a closed cycle external combustion engine that is effectively used in developing countries like Indonesia because it can utilize any source of heat energy. Supported by the scarcity of oil on earth, researchers around the world are developing the Stirling engine on a large scale to be used in all countries in the world.
7. In its application in everyday life, the Stirling engine is an environmentally friendly engine that does not cause pollution and is not noisy. The maintenance is not difficult

8. Stirling engines are used as water pump engines, power generating engines, motor engines.

Furthermore, the weaknesses of the Stirling engine are as follows:

1. Used drink cans do not last long enough if used continuously, because when heated over time the cans will become thin and damaged, so a material that is quite resistant to heat is needed if it is to be used for a long period of time.
2. In its application to everyday life, the Stirling engine is a machine that is quite expensive to manufacture and is quite dangerous because the combustion is outside the system, so further research is needed in the manufacture of Stirling engines on a large scale.

Then, based on the results of previous research, it was found that the use of a simple gamma type Stirling engine as a practicum tool was feasible and practical to use to support high school thermodynamics learning [18]. Furthermore, it is known that the implementation of simple Stirling engine teaching aids in learning can increase students' conceptual understanding of the subject of thermodynamics II as evidenced by the results of the pretest and posttest which were analyzed using a Normalized Gain of 0.67 [19]. In line with previous research, the results of this study also found that teaching aids are effective and practical and can be used as learning media.

The implications of this research for education, especially teaching physics, are that it can encourage studies on the efficacy of direct learning tools in teaching thermodynamics. Research may focus on how such tools impact student understanding, engagement, and long-term retention of thermodynamic principles. Then the creation of these demonstration tools may encourage research into new teaching methods. Scholars can explore how interactive tools such as Stirling engine models can be integrated into the curriculum to improve learning outcomes. This research has limitations, one of which is that the simplified model may not cover all thermodynamic principles. It may focus on certain aspects, ignoring nuances or advanced concepts, thereby providing a limited scope of understanding.

4. CONCLUSION

Based on the results of the research and development that has been carried out, it can be concluded that this research and development is in the form of a simple stirring machine teaching aid in the class XI high school thermodynamics subject along with worksheets, using the ADDIE model approach with stages of analysis, design, development, implementation and evaluation. This Simple Stirling Engine teaching aid has gone through a feasibility test with an expert validation assessment, namely media experts got a percentage of 92.4% in the very good category, material experts got a percentage of 80.6% in the good category, and total validation experts got a percentage of 80.6% with good category. 86.5% and can be categorized as very good. The results of product trials show an increase in response in small group tests, a percentage of 91.9% and field tests of 93.1%. For future research, the researcher recommends focusing on areas of development of teaching aids and how they impact student understanding. Further research could increase the efficacy, accessibility, and applicability of Stirling engine demonstration tools, thereby increasing their role in thermodynamics education and beyond.

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