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Development of Thermodynamics Learning With Empirical Approach and Portfolio Assessment Techniques

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ABSTRACT

Students face numerous challenges in comprehending thermodynamics concepts and principles. The empirical approach and portfolio assessment technique were used to encourage educators to determine good teaching strategies and motivate students. The purpose of carrying out this research was to develop thermodynamics teaching materials with an empirical approach and portfolio assessment techniques. This research uses a mix method, namely qualitative and quantitative with development research using the Borg and Gall models. This research was conducted on students majoring in Physics Education. Based on the validation results of material experts 91.9% and media expert validation 80.9% that this teaching material is feasible to use. The results of the one-party t-test were given treatment in the learning process, namely an empirical approach with a portfolio assessment technique. Then given a posttest or final test as evaluation material. The data obtained was then processed to test descriptive research data, data normality, hypothesis testing and N-Gain testing with the help of SPSS 22.0 for windows. With an average result 47.25 of pretest and 81.25 of posttest. The N-Gain results are in the medium and high categories and the average result is 0.64 which shows an increase in student results in thermodynamics courses. Students can get information through direct experience, making what they learn more tangible and learning more meaningful and exciting since it helps them to think critically.

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INTRODUCTION

Learning and experience have a close link. Learning is described as a continuous change in human beings involving knowledge and skills resulting from experiences that are actively acquired (Illeris, 2018). Physics is a form of science, so that its scope is also limited to the empirical world, namely things that are accessible to human experience. Learning about physics is one strategy to instill in kids a scientific mindset and method in order to produce a scientific effort or product. Learning physics is very important because knowledge of physics consists of many concepts and generally abstract principles. Because of that, there are many difficulties faced by students in understanding the concepts and principles of physics. Misconceptions are one of the causes of difficulties in the process of understanding students' concepts (Docktor & Mestre, 2014; Soeharto et al., 2019).

The learning approach is the starting point or point of view towards the learning process which refers to the view of the occurrence of a process which is still very general in nature in facilitating, inspiring, strengthening and backgrounding learning methods with a certain theoretical scope. The learning approach can also be interpreted as a path that will be taken by students and educators to achieve the goals of learning. Students' perception of assessment conditions has a positive relationship with their assessment learning results (Sæle et al., 2017; Leeuwenkamp et al., 2019; Negash et al., 2022). Activities that focus on assessment essentially help students identify aspects of their attitudes toward, as well as adjust, their sustainability education (Colomer et al., 2018). The learning approach is also a teacher's activity in choosing learning activities, namely a system to facilitate the implementation of the learning process and help achieve the goals that have been set in in curriculum. Teachers need to develop collaborative approaches to improve curriculum sustainability (Filho et al., 2018).

Learning with an empirical approach is a learning process that activates students and builds knowledge and skills through real experiences. In this case the empirical approach uses experience as a catalyst to help students develop their capacities in the learning process. Empirical study provides insight into science, offers implications for scientific learning, and provides models of how knowledge can be tested in practice (Kelly & Licona, 2018). This learning approach gives students the opportunity to decide what experiences to focus on, what skills they want to develop and how they build concepts from the experiences they have first hand. In order for the learning process to be effective, students must have the ability according to empirical learning theory: 1) concrete experience, students involve themselves fully in new experiences; 2) reflection experience, students observe and reflect on experiences from various aspects; 3) abstract conceptualization, students create concepts that integrate their observations into sound theories; 4) active experimentation, students use theory to solve problems and make decisions.

Efforts to improve the quality of education are obtained through improving the quality of learning and the quality of the assessment system. These two things are interrelated. Assessment and learning need to be developed and prioritized (Baird et al., 2017), assessment for learning can have a significant impact on student learning (Wiliam, 2018). A good assessment system will also produce good quality learning, and it improving how teachers help student to learn (Irons & Elkington, 2021; Suskie, 2018). Educational assessment is the process of collecting and processing information to assess student performance, and understanding student misconceptions and capabilities (Thibaut et al., 2018). A good assessment system will encourage educators to determine good teaching strategies and motivate students.

Portfolio is a different type of formative assessment that helps learners improve their skills when they gather their work and independently identify their strengths and flaws while being aware of the evaluation process, which improves their cognitive ability and autonomy (Djouama & Chelli, 2022). Generally, portfolios are assessed by educators and other parties or the wider community (Johnson, 2008). It provides opportunity to learn various references (Lukitasari et al., 2018; Novitasari et al., 2018), emphasised more than traditional assessment (Quansah, 2018), and recommended to be involved in students training (Aziz, 2018; Dayal & Cowie, 2019; Mahmud et al., 2018; Pahlevi et al., 2018). Portfolios assessment are as unique as the students who create them, because they give students choices, allow them to use their own learning style, and provide opportunities for advancement.

The problem faced in learning Thermodynamics in the Physics Department of Faculty of Mathematics and Science, Universitas Negeri Manado, is the lack of laboratory equipment to demonstrate the physical phenomena of the laws of Thermodynamics. The thermodynamics learning process that is taught is always centered on an emphasis on theory and students never carry out practicum. This is due to inadequate laboratory equipment for the Thermodynamics course in expressing the symptoms and principles and concepts of the laws of Thermodynamics. Thermodynamic learning is real learning where learning activities can not only be carried out in the classroom but can also be carried out outside the classroom. To understand the concept of the laws of thermodynamics can be done by observing the phenomena that exist around the surrounding environment. The empirical approach is a learning approach that involves students skills and feedback to play an active role based on real experience, and stimulates reflections on effective strategies of learning to teachers (Cornford, 2002; Keengwe & Kang, 2013). This learning approach assumes that learning activities will attract students' attention if what is learned is raised from what students have actually experienced. Some common challenges in learning thermodynamics are the interpretation of graphs, mastery of their physical equations and interpretations, comprehension of thermodynamic concepts, and use of these concepts in daily life (Husein et al., 2019). The intended thermodynamics lecture model with an empirical approach is to provide opportunities for students to observe phenomena in the surrounding environment related to the concept of the laws of thermodynamics. Through empirical learning it is also hoped that it can overcome the problem of inadequate laboratories with real learning from the experiences experienced by students.

In addition to using the right learning approach, what cannot be avoided is how the learning process experienced by the participants is assessed appropriately, because even though the learning process is appropriate, if it is not supported by appropriate assessment techniques it can result in the overall learning process not being optimal and will produce student learning outcomes that are not optimal either. To improve the quality of education can be pursued through improving the quality of learning and the quality of the assessment system (Mardapi, 2018). Thus, this research was carried out with the aim of knowing the effect of the empirical approach and portfolio assessment techniques in thermodynamics courses.

RESEARCH DESIGN

The research carried out is a type of Research and Development (R&D). The purpose of this development research is to develop and validate products and test the effectiveness of certain products. Research and Development (R&D) is conducted to develop existing teaching materials into teaching materials that are more effective in learning activities. In this case the research aims to develop thermodynamics teaching materials with an empirical approach and portfolio assessment techniques.

This study used the research and development method by following the stages of development research adapted from Borg and Gall (Gall et al., 2007). This research was conducted on fourth semester students majoring in Physics Education 2021/2022, classified as follows.

1. Planning

The main activities in the planning step include:

a. Formulation of goals to be achieved

The first step is to determine the objectives to be achieved in the research. The goal setting is based on the limitations of the material being developed.

Goal setting was also carried out as a reference for compiling a map of achievements to be achieved in this development research. Because by setting the research objectives, indicators of competency achievement can be identified in the material of the Laws of Thermodynamics.

b. Determination of Success Criteria

After setting the goals to be achieved in the research on developing Thermodynamics teaching materials, the researcher needs to determine the criteria for research success.

2. Exploratory Studies

The goal in this stage is to establish and define the learning requirements which begin with an analysis of the objectives of the material to be developed in the learning tool by directly observing the working principle of the refrigerator associated with the phenomena of the laws of thermodynamics, so as to obtain the concepts and physical principles of the laws of thermodynamics.

3. Development of Initial Forms of Products

The activity in this step is in the form of making a product design that will produce the desired initial shape. This activity requires the support of expert review and improvement which can take place many times as shown in Figure 1 below.

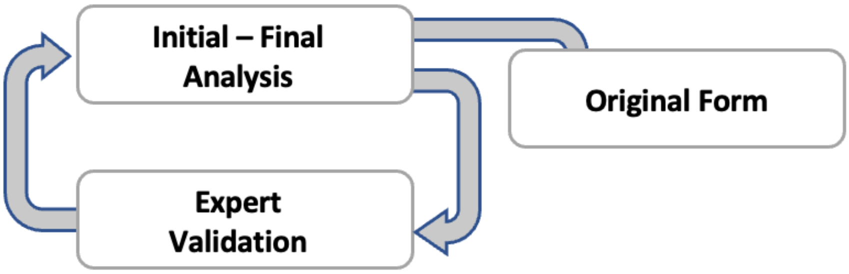

Figure 1. Expert review procedure to produce initial products

Development activities carried out for the manufacture of initial product designs based on the process of reviewing several Thermodynamics text books with the aim of knowing the advantages and disadvantages of textbooks, in this case, is the study of Thermodynamics textbooks through identification-analysis of material structures, and classification of the characteristics of Thermodynamics teaching materials.

4. Validation

Before the teaching materials are tried out, the researcher conducts expert validation by paying attention to several aspects which will then be included in the expert validation questionnaire or questionnaire, these aspects are:

a. Product aspect
b. Clarity of instructions for use
   The clarity of the instructions for use here are the steps presented in the process of making the teaching materials in accordance with the Thermodynamics learning material and carried out in a coherent manner.
c. Legibility
   The teaching materials presented can be read properly and do not even have a double meaning in writing, in order to make it easier for students to understand the systematics of thermodynamics teaching materials. The material discussed in the teaching materials has good systematics in its presentation.
d. The quality of the display of images and tables
   Clarity in the appearance of images and tables both in words and colors.
e. Instructional aspects
   Instructional aspects include clarity of core competencies, basic competencies, indicators and even learning objectives to be achieved, clarity of learning instructions in the syntax of learning designs, ease of understanding the material presented, breadth and depth of material, accuracy of presentation order, interactivity, accuracy of evaluation, clarity of feedback.

The data obtained is qualitative and quantitative data. Qualitative data is in the form of additional assessments or suggestions from the validator, while quantitative data comes from a Likert scale assessment questionnaire. Expert validation is carried out by experts in the field of Physics which is useful for reviewing the initial product.

5. Product Trials

The field test is a product usage test on representative and appropriate target subjects. The trial was conducted in order to determine the quality of the product. The design used for the field test is quasi-experimental. This test is carried out according to the following diagram.

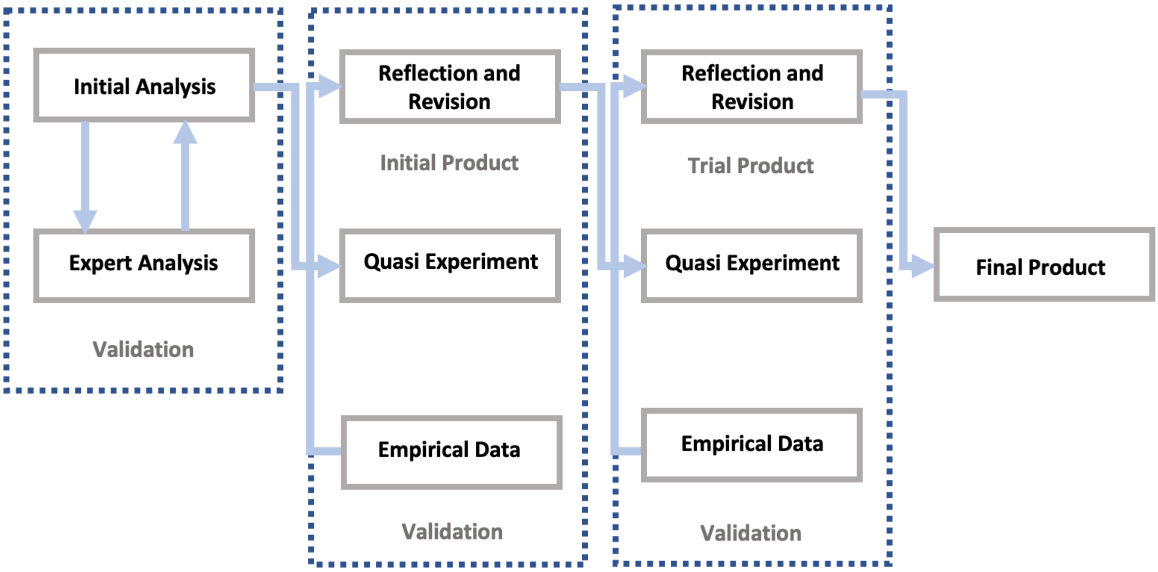

Figure 2. Product validation procedures in field tests

Validation through field tests was carried out with a quasi-experimental design carried out on a limited scale using the initial product and in actual situations in learning using trial products.

a. Small group test

After the product has been designed, it is tested first in small groups. This trial was carried out by testing the development of practicum-based physics teaching materials to a group of students consisting of 5 students of the Forth Semester of Physics Study Program class of 2021/2022.

6. Revision

Before testing the thermodynamic material with an empirical approach and portfolio assessment in the field, the teaching material was revised based on the responses given by students in small group trials or limited trials.

a. Large group test

Testing can be carried out with experiments, namely to evaluate the process and achievement of student learning outcomes that are tested in the field, namely fourth semester students of the Physics Education Department.

b. Revision based on field test

At this stage the field test results are used as a reference for revision before the device product is disseminated. This activity can be carried out according to the needs of researchers depending on how many test activities are carried out before dissemination.

c. Revision based on field test

At this stage the field test results are used as a reference for revision before the device product is disseminated. This activity can be carried out according to the needs of researchers depending on how many test activities are carried out before dissemination.

7. Product Dissemination.

Product dissemination is a final stage in development research activities. Dissemination in research on the development of thermodynamics teaching materials with an empirical approach and portfolio assessment on the material of the laws of thermodynamics is only carried out in a limited manner with the resulting products being reported at scientific meetings or scientific journals. The location in this research is the Department of Physics Education, Faculty of Mathematics, Natural and Earth Science, Universitas Negeri Manado. The object in this development research is the development of Thermodynamics teaching materials on the material of Thermodynamic Laws in the form of Thermodynamics learning tools. The subjects in the development research are forth semester students of Physics Education. The research instruments used were reviewer assessment sheets, group student response sheets, and observation assessment sheets. Data analysis used in this development research has three techniques including, learning content analysis, descriptive analysis, and analysis of test results.

Analysis of test results; In field trials, data were collected using questionnaires and achievement tests. Final ability data (Post-test) were analyzed using the t-test to determine the significance of increasing students' class understanding of concepts using Thermodynamics teaching materials with an empirical approach and portfolio assessment.

The method used in this study was a pre-experimental method with a one group pretest-posttest design, by using SPSS 22.0 by conducting descriptive analysis tests, normality tests, hypothesis tests and N-gain tests.

Table 1. Design of one group pretest-posttest

O_1	X	O_1
Pretest	Treatment	Posttest

RESULTS AND DISCUSSION

Results

The results of the calculation of the material expert validation are 91.9% with very suitable criteria for use and media expert validation is 80.9%, by looking at the eligibility criteria table as follows.

Table 2. Media eligibility criteria

	Score in percent (%)	Eligibility Category
1	< 21%	Very not feasible
2	21 – 40 %	Not feasible
3	41 – 60 %	Decent Enough
4	61 – 80 %	Feasible
5	81 – 100 %	Very feasible

(Ernawati & Sukardiyono, 2017)

The results of calculating the small group trial data of 5 students obtained 77.4% with the appropriate criteria for large group trials. The results of the large group trial obtained 81.25% if you look at the feasibility table above, it is called feasible.

Furthermore, evaluating the results of responses from students about Thermodynamics teaching materials with an empirical approach and portfolio assessment results obtained: Very feasible = 54.8%, Feasible = 85.2%, and Not feasible = 0%. From the results of the evaluation of the validation of material experts and media experts as well as student responses to the learning modules developed, it can be concluded that the learning modules developed by researchers are very suitable for use in thermodynamics learning

Table 3. Large group descriptive statistical test results

Statistics		Statistical Results	
		Pretest	Posttest
1.	Mean	47.25	81.25
2.	Median	45.00	80.00
3.	Modus	45	80
4.	Std. Deviation	4.993	6.663
5.	Varians	24.934	42.397
6.	Range	20	20
7.	Minimum Score	40	70
8.	Maximum Score	55	90
9.	Sum	945	1625

Based on the results of the pre-test processed using SPSS.22 for windows, a total score of 9455 was obtained, the mean value was 47.25 with a standard deviation of 4,993, the median value was 45.00, the mode value was 45, the variance was 24,934, range 20 with the maximum value is 55 and the minimum value is 40. While the results of the post-test obtained a total score of 1625, the mean value is 81.25, with a standard deviation of 6.663, the median value is 80.00, the mode value is 80, the variance is 42.397, the range is 20 with the maximum value 90 and the minimum value is 70.

Table 4. Normality test result

Result	Asymp. Sig. (2-tailed)	Level of significant (α)
Pretest	.220	0.05
Posttest	.075	

Based on the results of the pretest normality test, it is known that the significance is 0.075 and the posttest is known to have a significance value of 0.022 ± 0.05 so that it can be concluded that the pretest and posttest data are normally distributed.

Table 5. Hypothesis test result

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	pretest – posttest	-26.250	9.301	2.080	-30.603	-21.897	12.621	19	.000

Based on Table 5, the value of Sig. (2-tailed) is 0.000 < 0.05 then H_0 is rejected and H_1 is accepted. The results of testing the hypothesis with (t-test), at the significant level (α) = 0.05 obtained t_{count} = 12.621 and t_{table} = 2.074. So t_{count} = 12.621 > t_{table} = 2.074 which means reject H0. Therefore it can be concluded that H_1 is accepted and H_0 is rejected. So it can be concluded that through the influence of the empirical approach and portfolio assessment techniques in thermodynamics lectures can improve the results of students or the hypothesis is accepted.

Table 6. Hypothesis test result

No.	N-Gain	Category	Number of Student	Percentage (%)
1.	$g < 0{,}3$	Low	0	0
2.	$0{,}3 \leq g \leq 0{,}7$	Moderate	11	55
3.	$g > 0{,}7$	High	9	45
	Sum		20	100

Table 6 shows that there were 9 students with N-gain scores in the high category, 11 students in the medium category and no students in the low category. The average gain score is included in the medium category is 0.64.

Discussion

Based on the results of the initial analysis, the highest pretest score was 55 and the lowest score was 40. Then the treatment was given in the form of an empirical approach with portfolio assessment techniques in thermodynamics lectures for 4th semester students majoring in Physics education at Faculty of Mathematics and Science, Universitas Negeri Manado. Then proceed with giving a final test or evaluation and a significant increase in student results is obtained. Based on the results of the descriptive analysis, scores were obtained which also showed an increase obtained from students in the thermodynamics lecture process where the highest post-test score was 90 and the lowest score was 70.

The increasing score shows that portfolios assessment encourages and motivate the student to improve scientific attitude and affects the learning outcome. This is consistent with earlier research, where portfolios assessment provides a means to collect feedback, reflect on the importance of assessment feedback, and develop a learning plan (Kulasegaram & Rangachari, 2018), and it improve the efficiency of scientific activities (Piterska et al., 2019; Dewi et al., 2022). The quality of the assessment system in a learning process is inseparable from the use of assessment techniques, because the use of inaccurate assessment techniques will greatly affect students, both in terms of learning motivation, or interest in learning which will ultimately affect further student learning outcomes.

The increase in results obtained by students was also strengthened by the results of the data normality test which was carried out and it was proven that the data were normally distributed. Likewise with the results of research hypothesis testing which shows that the hypothesis that has been built at the beginning is declared acceptable. Likewise with the results of the N-Gain test which showed that no students experienced an increase in the low category on the N-Gain test. The average increase in students is in the medium and high categories. Through the results of this test, it can be concluded that through an empirical approach with portfolio assessment techniques it can improve student learning outcomes in thermodynamics courses.

The empirical approach is considered in accordance with the implementation of thermodynamic lectures which are considered by some students to be quite complicated to understand the concepts of thermodynamic laws. Therefore, the empirical approach is an option in the implementation of thermodynamics lectures because its implementation refers to real experiences experienced by students which can help students understand the concept of thermodynamic laws.

The selection of portfolio assessment techniques is also appropriate considering that many students attend and do work. This assessment is a collection of student work with a specific and integrated purpose that is selected according to established guidelines. Instructor should be equipped with good knowledge on how to perform portfolio assessment and how portfolio assessment is an effective and efficient method (Tong, 2023). Indeed, this assessment does not stimulate students in terms of discovery so that it does not involve observation of symptoms or phenomena around daily life, but coupled with an empirical approach that uses real experience as a source of learning can help students in lecture activities. It was explained by previous studies that the portfolio as a collection of student work that is arranged in a systematic and organized manner as a result of the learning effort that has been carried out within a certain period of time (Clarke & Boud, 2018; Gede, 2018; Steen-Utheim & Hopfenbeck, 2019). From the several opinions above, portfolio assessment is a collection of student work to get an overview of students' abilities to express opinions in making assignments.

Previous research shows that there are significant differences in teacher approaches to assessment, resulting in different learning cultures for students (Coombs et al., 2018). From the results of this study, it was found that Thermodynamics lectures are better with an empirical approach with portfolio assessment techniques, because with this assessment students can show the development of students' abilities and performance in a certain period and make works obtained from studying the symptoms experienced and can help students in understanding concepts in lecture activities.

Thermodynamics learning has material characteristics that contain phenomena that are closely related to events related to the surrounding environment, therefore in the teaching process the lecturer should choose learning models and assessment techniques that are in accordance with the characteristics of the material and the characteristics of students. As obtained from this research, the combination of empirical approach with portfolio assessment technique is very influential on student learning outcomes in learning thermodynamics.

This research shows learning with an empirical approach can enrich the insight and knowledge possessed by students because the surrounding environment and real experience are learning resources that can be used as an independent and imaginative laboratory that can demonstrate the concepts and principles of the laws of thermodynamics, while the portfolio assessment technique is very suitable when combined with an empirical approach where students are trained to learn through their experiences in the surrounding environment and apply it in the form of work and work to then become material for assessment.

Based on the results of this research, it is obtained that lectures with an empirical approach link the material taught with real situations and experiences experienced by students and encourage students to make connections between the knowledge they have and its application in everyday life. This means that the material or concept that has been learned is not easily forgotten and what is learned is considered useful, a person will be motivated to learn more in acquiring knowledge so that learning is an enjoyable and challenging activity.

CONCLUSION

It is highly acceptable to employ portfolio assessment methods and an empirical approach when creating teaching materials for thermodynamics courses. The research has the implication that teaching thermodynamics using materials that employ empirical approaches and portfolio assessment techniques results in very high learning outcomes for students, and that teaching thermodynamics should follow suit. This learning is highly effective at boosting student learning activities. When students get information based on firsthand experience, their learning is more tangible and engaging because it develops their critical thinking skills. It is preferable for lecturers to evaluate student learning activities using portfolio assessment when grading assignments. The empirical approach and portfolio assessment in relation to students' retention and self-efficacy in physics will be explored in our upcoming research.

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