JPPS (Jurnal Penelitian Pendidikan Sains)
Homepage : https://journal.unesa.ac.id/index.php/jpps
Email : jpps@unesa.ac.id

p-ISSN : 2089-1776 ; e-ISSN : 2549-1597
JPPS, Vol. 12, No. 1, November 2022 : 56-68

(Jurnal Penelitian Pendidikan Sains)

Effect of Project-Based Learning and Science Literacy Ability on Critical Thinking Skills in Virtual Learning of the Thermodynamics Course

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DOI: https://doi.org/10.26740/jpps.v12n1.p56-68

Sections Info

Article history:
Submitted: October 27, 2022
Final Revised: November 05, 2022
Accepted: November 06, 2022
Published: November 27, 2022

Keywords:
Critical Thinking Skills
Project-based Learning
Scientific Literacy Ability
Virtual Learning

ABSTRACT

Research aims to find the effect of project-based Learning and scientific literacy skills on students' critical thinking skills 20 students in virtual learning of the Thermodynamics class at the Physics Education Study Program. The research design used the three-variable regression technique, which consists of two independent variables, namely project-based Learning (X_1), the scientific literacy ability (X_2), and the dependent variable, namely critical thinking skills (Y). Data collection techniques include observation sheets, questionnaires with a Likert scale, and evaluation of critical thinking skills. The results of the data analysis show that there is no partial effect of project-based learning on students' critical thinking skills, and the scientific literacy ability variable partially affects the critical thinking skills variable. Project-based Learning and scientific literacy skills significantly affect critical thinking skills. This research implies that there is evidence that Thermodynamics learning is not enough to apply project-based learning but must be equipped with literacy learning because, with a combination of these two things, students' critical thinking skills can increase significantly.

INTRODUCTION

Critical thinking is related to the ability to identify, analyze, and solve problems faced appropriately based on the analysis and knowledge they have. Critical thinking is one of the essential skills in 21st-century education that students need to master (Hemas, 2021). Ennis (2015) states that critical thinking skills are reflective thinking patterns focused on deciding what to believe or do. The purpose of critical thinking is to keep someone from making wrong and hasty decisions that cannot be accounted for. Critical thinking characteristics are evaluation when thinking, always thinking reflectively, using logic, and systematically. Antika et al. (2017) state that students with critical thinking abilities can analyze problems, draw conclusions from various aspects and points of view, and determine solutions to solve these problems. In addition, critical thinking is an organized, systematic process that allows students to formulate and evaluate the evidence, assumptions, logic, and language that underlies the statement and find answers to these problems.

Efforts to improve critical thinking skills must be made by paying attention to the phases of critical thinking skills (Davies & Barnet, 2015). Facione (2015) states that critical thinking skills include cognitive skills and character (disposition). Cognitive skills that are the core of critical thinking include the following skills: interpret (interpretation), analyze (analysis), evaluate (evaluation), conclude (inference), explain (explanation), and regulate yourself (self-regulation). Through science lessons or other disciplines, critical thinking skills can be trained with learner-centered learning. Learner-centered learning refers to constructivism theory which places students as

individuals with seeds of knowledge within students who require various activities or activities to develop them into meaningful understanding (Rahayuni, 2016).

Science lessons and education play an essential role in creating reliable and quality human resources in facing the challenges of the globalization era. Based on a report from the United Nations Development Project (UNDP) in the Human Development Index (HDI), Indonesia has ranked 114 countries among various countries in the world. This data shows the low quality of science education in Indonesia. Science (basic science), the foundation for developing individual thinking patterns, becomes a prominent supporter in problem-solving, especially with practical science (Sunaryo, 2019). As part of education in general, science plays a vital role in preparing students who can think critically, creatively, and logically and take the initiative in responding to societal issues caused by the impact of the development of science and technology. The science education process should emphasize providing hands-on experience to develop competencies to explore and understand the natural surroundings scientifically.

Physics is a part of science. Physics studies natural phenomena involving matter, energy, and interactions through observation, experimentation, and analysis. The essence of Physics is Physics as a product, attitude, and process. Physics as a product is a collection of knowledge in the form of facts, concepts, and principles. The science learning process should assist students in achieving the goals, namely (1) Building meaningful knowledge and knowledge; (2) Providing freedom in developing thinking, creativity, and critical skills; (3) Applying the pre-existing knowledge to learn and solve problems and make decisions. Lecturers are encouraged to produce active, interactive, and fun.

One part of science that is closely related to the practical application of physics and technology to various aspects of everyday life is thermodynamics. Thermodynamics is closely related to the universe and essential to human life. Rusydi (2017) suggested that Thermodynamics is a basic knowledge related to energy and has long been an essential part of the engineering curriculum. Thermodynamics is a subject related to energy and is one of the materials needed to understand natural phenomena. Thermodynamics studies relationships involving heat, mechanical work, and other energy transfer aspects in refrigerators, heat pumps, internal combustion engines, etc. These relationships are governed by the four laws of thermodynamics which are now some of the most important fundamental laws in nature (Wanjala & Buers, 2015).

The Physics Education Study Program curriculum at the University of Palangka Raya places the Thermodynamics course as one of the expertise courses. This course aims to strengthen students' understanding of fundamental physics and equip students to take advanced courses. The thermodynamics course is one of the courses that contain physics concepts that physics education students must master. The concept of Thermodynamics is closely related to events in everyday life. Students need to understand the concept of thermodynamics to explain Physics phenomena in everyday life. The results of the research by Husna et al. (2021) suggest that students' difficulty in constructing a scientific conceptual understanding of physics is due to the misconceptions developed by students based on perceptions obtained from everyday life. Student's difficulties in constructing a scientific conceptual understanding of physics are also caused by misconceptions that develop in students based on perceptions obtained from everyday life. Students who need help understanding the

concepts of Physics can certainly not be able to explain everyday phenomena using Physics concepts. Students cannot relate one concept to another because each concept has yet to be entirely constructed in their thinking. Students' thinking ability to master Physics concepts requires basic thinking skills as well as complex (higher-level) thinking skills, including critical thinking skills. The principles of the scientific approach must be adapted to the developments and demands of the times. Science learning must be directed at the principle of student independence. This concept is taught in the principle of diversity by the principle of independent Learning (Shabazi et al., 2016)

Henderson & McKinney (2016) state that in learning science, language skills guide learning. Furthermore, the understanding is that language governance is vital in Learning—language functions as a guide in the learning process. Scientific literacy has a broad meaning, is open, free from benchmarks, and allows teachers and students more freedom to choose from various science content and scientific methodologies. Science learning directs students to be literate in science, so students must have the ability to think critically and solve problems. So that they can understand and critically remember not only information but also the achievement of learning objectives in a broad sense, namely personality science literate students.

Scientific literacy is an indicator of a country's education and resource quality. Another factor that affects scientific literacy is the ability to think critically (Critical Thinking). Mery et al. (2021) state that scientific literacy has been defined in various ways, emphasizing students' ability to use scientific knowledge in real-world situations. Several countries have established scientific literacy as the goal of science education. Scientific literacy ability can be defined as the individual's ability to identify scientific facts, use appropriate research methods to obtain the required scientific evidence, and analyze and interpret this evidence so that meaningful conclusions can be obtained (Rizkita et al., 2016). Every citizen at various levels of education needs scientific knowledge, understanding, and abilities. Scientific literacy is a must and a necessity for every student. Scientific literacy in Indonesia is still low, as evidenced by the test of scientific ability carried out in the TIMSS (Trends in International Mathematics and Science) study for fourth and eighth grades in mathematics and science, which is held every four years. The results of the TIMSS study in the field of science in 2015 showed Indonesia was ranked 44th, followed by 49 countries, showing an average science achievement score of 397, a slight increase from 2011. Indonesian students' science achievement is below the average. Namely, 500 only reached the Low International Benchmark (Syamsul & Novaliyosi, 2019).

One way to develop scientific literacy is by attracting student involvement in learning. Lecturers can create a pleasant learning atmosphere, make students ready to learn better, and understand Thermodynamics so that lecturers can use various learning models under Thermodynamics learning, including project-based learning models (Project Based Learning). Project-based learning is a type of learning that organizes students to build their knowledge independently through investigation and discussion to solve problems in order to achieve the planned targets (Prabawati & Agustika, 2019; Jagantara et al., 2014). The results of the research by Desi et al. (2017) found that the ability to explain scientific phenomena is closely related to scientific literacy competence, including the ability to evaluate and design scientific investigations and

the ability to interpret scientific data and evidence. Applying the suitable model can also increase students' interest and literacy skills. Almahida & Gamaliel (2020) revealed that using the PjBL learning model effectively improved students' critical thinking skills.

The Thermodynamics course, as one of the Physics Education Study Program courses at the University of Palangka Raya, is also carried out virtually. Thermodynamics studies relationships involving heat, mechanical work, and other energy transfer aspects in refrigerators, heat pumps, internal combustion engines, etc. These relationships are governed by the four laws of thermodynamics which are now some of the most important fundamental laws in nature (Wanjala & Buers, 2015).

Alqudah et al. (2020) defined virtual learning/e-learning as technology-based learning with learning materials sent electronically to students via computer/internet networks so that students can acquire knowledge without facing the teacher in class. Virtual learning is an umbrella term for all technology-enabled learning using various teaching and learning tools, such as telephone, audio, videotape, satellite, or computer transmission. Thus, virtual learning makes it easier for educators and students to conduct distance learning (Ali & Maksum, 2020). They are learning by implementing various approaches, models, and methods in Thermodynamics learning to make students able to understand the abstract and macroscopic concepts of Thermodynamics that are difficult to describe in absolute terms without ignoring the need for learning that tends to use a mathematical approach in teaching the concepts of Thermodynamics. Singh et al. (2021) argue that by providing opportunities for students to interact with various learning resources available through the Internet, students' lifelong learning skills will increase. Virtual discussion activities will also positively affect students' responsible and professional communication skills. Students are expected to be actively and enthusiastically involved in constructing thermodynamic concepts because understanding complex and abstract concepts can be done when they are involved in constructing a concept in their mind and science skills through the scientific process (Risamasu, 2016). The results of Sim et al. (2020) research determined that students were moderately enthusiastic about online learning and showed an increased interest in progressive online learning approaches.

The thoughts of various experts, facts in the field, as well as various relevant research results that have been described above are the rationale for the need for a study that aims to apply a project-based learning model combined with scientific literacy ability to train critical thinking skills the students of the Physics Education Study Program at the University of Palangka Raya in virtual learning of the Thermodynamics course. The study results are expected to be an evaluation material for implementing Thermodynamics learning as well as other courses with similar characteristics to Thermodynamics. This study aims to determine the effect of PjBL and scientific literacy ability on students' critical thinking skills in Virtual Learning of The Thermodynamics Course.

RESEARCH METHOD

The aim to be achieved in this research is to describe and reveal the effect of project-based learning models and scientific literacy ability on students' critical thinking skills, so the researchers used explanatory research (explanatory research). Explanatory

research highlights the relationship between research variables and tests previously formulated hypotheses. Therefore it is also called hypothesis testing research (testing research). This study uses quantitative research with correlation research in a causal form with three variables, namely project-based Learning (X_1), scientific literacy skills (X_2), and critical thinking skills (Y). Data collection techniques include observation sheets, evaluation of scientific literacy, questionnaires or questionnaires with a Likert scale, and evaluation of critical thinking skills. The data analysis technique used multiple regression analysis because this study used two or more independent variables, T-test analysis (partial effect) and F-test analysis (simultaneous effect).

Population and Sample

The sampling technique of this research is total sampling, a technique where the number of samples is the same as the population. The reason for taking total sampling is that the total population is less than 100, so the entire population is used as a research sample. The population in this study were 20 students of the Thermodynamics class of the Physics Education Study Program at the University of Palangka Raya for the 2021/2022 academic year.

Instrument and Procedures

The research instrument consisted of: an instrument for observing lecturer activities in project-based thermodynamics learning, an evaluation instrument for scientific literacy, and an instrument for evaluating critical thinking skills. Scientific literacy indicator uses five parts of the Gormally indicators: 1) identify valid scientific arguments, 2) evaluate source validity, 3) evaluate the use and misuse of scientific information, 4) read and interpret graphical representations of data, and 5) solve problems using quantitative skills, including probability and statistics. Indicators of critical thinking skills using Ennis' critical thinking indicators: (1) formulating the main points of the problem; (2) revealing the existing facts; (3) choosing a logical argument; (4) detecting bias with different points of view; (5) concluding. All instruments have been developed by team researchers and validated by three validators, lecturers colleagues. The research flowchart is shown in Figure 1.

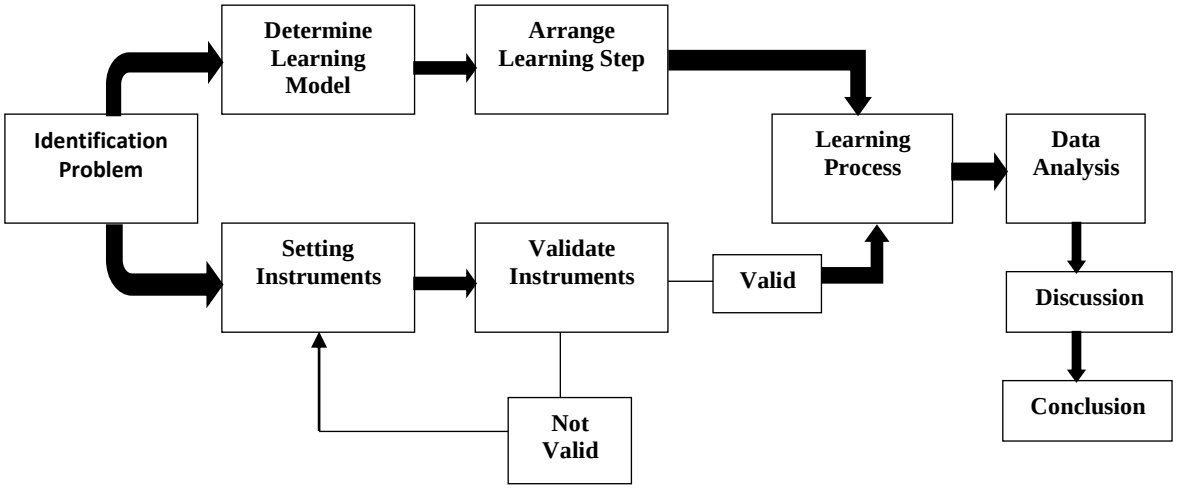

Figure 1. Research flowchart.

Data Analysis

The results of the instrument feasibility analysis show that the instrument's validity score for Instrument of Observing Lecturer Activities in PjBL-Based Thermodynamics Learning, Instrument of Scientific Literacy Skills, and Assessment instrument Critical thinking skills has very valid criteria. The comparison shows that r-count ≥ r-table, with a significant level of 5% as the reason for making decisions instrument. If r-count ≥ r-table, it can be concluded that the instrument is valid (Arikunto, 2007). The calculation reliability coefficient using Cronbach Alpha analysis is 0,9, included in the reliable criteria (Utami & Derius, 2020).

RESULTS AND DISCUSSION

Results

The research data were analyzed using the SPSS 16.0 application, and the results were obtained as shown in Tables 1 and 2. The effect of Project-Based Learning and Scientific Literacy Ability on critical thinking skills as the answer to this research's first and second hypotheses can be seen in Table 1.

Table 1. Project-based learning and scientific literacy ability partial test on critical thinking skills.

Model		Unstandardized Coefficients		Standardized Coefficient		
		B	Std. Error	Beta	t	Sig
1	(Constant)	30.067	15.863		1.929	.071
	Project-Based Learning (X_1)	.001	181	001	.007	.995
	Scientific Literacy Ability (X_2)	.603	114	791	5.290	< .001

a. Dependent Variable: Critical Thinking Skills (Y)

The first t-test was conducted to determine whether Project-Based Learning (X1) had an effect on Critical Thinking Skills (Y). The output of the SPSS coefficient analysis is shown in Table 1. It is known that the significance value (sig) of the Project-Based Learning (X_1) variable is 0.995. Because the value of sig 0.995 > probability 0.05, it can be concluded that H_1 or the first hypothesis is rejected. That is, Project-Based Learning (X_1) has no effect on Critical Thinking Skills (Y). The analysis result, also contained in Table 1, is that the t-value of the probability variable is 0.007. Because the t arithmetic value is 0.007 < t table 2.109, it can be concluded that H_1 or the first hypothesis is rejected. This means there is no effect of Project-Based Learning on Critical Thinking Skills.

The second t-test was conducted to determine whether Scientific Literacy Ability (X_2) affected Critical Thinking Skills (Y). The output of the SPSS coefficient analysis is shown in Table 1. It is known that the significance value (sig) of the Scientific Literacy Ability (X_2) variable is 0.001. Because the value of sig 0.001 < probability 0.05, it can be concluded that H_2 or the second hypothesis is received. It means that there is an influence of Scientific Literacy Ability (X_2) on Critical Thinking Skills (Y). The analysis result, also contained in Table 1, is that the t-value of the probability variable is 5.290. Because the t arithmetic value is 5,290 > t table 2.109, it can be concluded that H_2 or the

second hypothesis is received. This means that there is an influence of Scientific Literacy Ability (X_2) on Critical Thinking Skills (Y). Testing of the influence of Project-Based Learning and Scientific Literacy Ability simultaneously on Critical Thinking Skills is carried out by conducting the F test. SPSS output results in multiple regression analysis are in Table 2.

Table 2. ANOVA output.

Model		Sum of Squares	df	Mean Square	F	Sig
1	Regression	210.173	2	105.087	14.220	< .001[b]
	Residual	125.627	17	7.390		
	Total	335.800	19			

a. Dependent Variable: Critical Thinking Skills (Y)
b. Predictors (Constant), Scientific Literacy Ability (X_2), Project-Based Learning (X_1)

The output of the SPSS Anova analysis is shown in Table 2. It is known that the significance value (sig) of the Scientific Literacy Ability (X_2) variable is 0.001 < 0,05. According to the basis of decision-making in the F test, it can be concluded that the third hypothesis is accepted, or in other words, Project-Based Learning (X_1) and Scientific Literacy Ability (X_2) simultaneously affect the Critical Thinking Skills (Y). The ANOVA analysis result, which is also contained in Table 2, is that the calculated F value is 14,220 > 3,550 (F Table). Then, as the basis for decision-making in the F test can be concluded that the third hypothesis is accepted, or in other words, Project-Based Learning (X_1) and Scientific Literacy Ability (X_2) simultaneously affect the Critical Thinking Skills (Y).

Discussion

Project-Based Learning and Critical Thinking Skills in Virtual Learning Class

The first hypothesis test results show no significant effect between Project-Based Learning and Critical Thinking Skills in virtual learning classes. The results of testing the first hypothesis show no significant effect between project-based learning and critical thinking skills (Table 1). This strengthens the theory that states that Project-based Learning is a student-centered form of instruction that is based on three constructivist principles: Learning is context-specific, learners are involved actively in the learning process, and they achieve their goals through social interactions and the sharing of knowledge and understanding (Kokotsaki et al., 2016). Assistance is needed in completing the project, which can be in the form of references, discussion partners, or other sources.

Project-Based learning is the use of classroom projects in learning and Assessment to facilitate students in constructing their meaningful idea and knowledge in the real world. Project-Based Learning is centered on the learners and affords learners the opportunity for in-depth investigations of worthy topics. Ni Made et al. (2016) research stated that applying the project-based learning model assisted by virtual media can also improve students' mastery of physics concepts.

A project is an assignment aimed at having the students produce a product. Students are expected to create a real thing based on the teaching material. However, the results of this study are by reports of research results that have been carried out previously,

which found that variables can influence critical thinking skills variables: project-based Learning (Almahida & Gamaliel, 2020; Sunaryo, 2019; Jagantara et al., 2014; Issa & Khataibeh, 2021). Project-based learning has also been compared with other pedagogical practices, such as experiential or collaborative learning. As Kokotsaki et al. (2016) argue, project work is a collaborative form of learning as all participants need to contribute to the shared outcome and have elements of experiential learning with active reflection and conscious engagement rather than passive experiences being essential. The results of this study show that the partial implementation of Project-Based Learning without adequate scientific literacy and collaboration skills cannot build students' critical thinking skills.

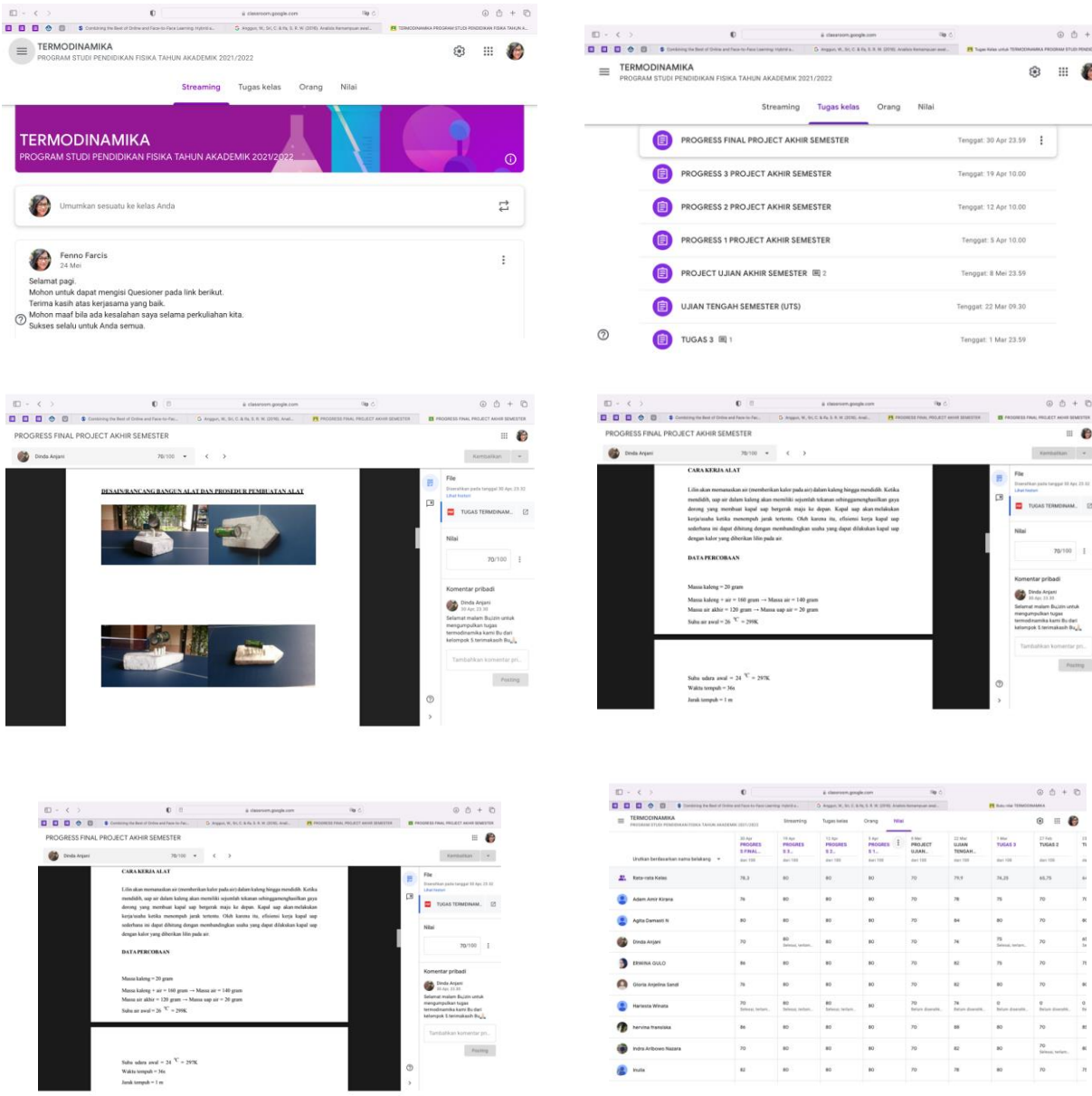

Figure 2. Thermodynamic course virtual learning process

Scientific Literacy Ability and Critical Thinking Skills in Virtual Learning Class

Scientific literacy comes from a combination of two Latin words, namely literatus, marked by letters, literacy or education, and scientist, which means knowledge. Scientific literacy is the act of understanding science and applying it to the needs of society. The definition of scientific literacy, according to Fadila et al. (2020), is a person's ability to understand science, communicate science (oral and written), and apply scientific knowledge to solve problems so that they have a high attitude and sensitivity to themselves and their environment in making decisions based on scientific considerations. The initial stages of the second research objective, namely to determine the effect of scientific literacy skills on students' critical thinking skills, are the preparation of tests of scientific literacy skills and using indicators adapted from Gormally et al. (2012).

The results of the second hypothesis test show a significant effect between Scientific Literacy Ability and Critical Thinking Skills (Table 1). The results of this study are per the report on the results of research that has been carried out, which found that scientific literacy and critical thinking skills together with mastery of basic concepts of science (Juhji & Mansur, 2016). Rahayuni's research (2016) found a strong correlation between critical thinking skills and science literacy. Ivayuni et al. (2022) found a relationship between scientific literacy and the critical thinking of prospective teacher students and that understanding science requires good thinking, especially critical thinking. The results of this study mean that students with high scientific literacy skills can have high critical thinking skills. Vice versa, students with low scientific literacy skills have low critical thinking skills.

Students' ability in scientific literacy was reviewed using seven indicators of scientific literacy ability. The seven indicators refer to the indicators of scientific literacy ability from Gormally et al. (2012). The seven measures of scientific literacy indicators are (1) identifying valid scientific opinions, (2) conducting an effective literature search, (3) understanding the elements of research design and how they impact the findings/conclusions, (4) making accurate graphs of the data; (5) solving problems using quantitative skills, including basic statistics; (6) understand and interpret basic statistics; (7) perform inferences, predictions, and draw conclusions based on quantitative data. The indicator of scientific literacy ability developed by Gormally et al. (2012) was chosen because it is straightforward to implement, simple, and represents all scientific literacy skills. The results of the student's scientific literacy ability test showed that a higher student's scientific literacy ability was an indicator of identifying valid scientific opinions search with a percentage of 65%. While the results of the analysis of the scientific literacy skills of students who had a lower understanding and interpreted basic statistics with a percentage of 30%.

Project-Based Learning, Scientific Literacy Ability, and Critical Thinking Skills in Virtual Learning Class

The results of the third hypothesis test show an effect between the variables of project-based learning and scientific literacy ability on critical thinking skills. This can be seen in Table 2. This study found a joint influence between the project-based learning variable and the scientific literacy ability variable on the critical thinking skill variable.

The results of this research also at the same time sharpen the results of research by Ivayuni et al. (2022), who found a link between critical thinking skills and scientific literacy. However, no analysis was carried out on whether the two variables had the same influence or were influenced by project-based learning. The same thing is also found in the research results of Rahayuni (2016), that critical thinking skills influence students' scientific literacy achievement.

Suwono et al. (2015) argue that scientific literacy emphasizes the importance of thinking and acting skills by mastering thinking by recognizing and responding to several issues that develop in society. Scientific literacy can develop in line with the development of reasoning skills and academic thinking in the context of social life so that the mastery of the concepts of Thermodynamics can be beneficial. Science literacy skills trained in project-based learning further strengthen the formation of students' critical thinking skills. This finding strengthens the results of research by Almahida et al. (2020), who found that using the STEM-based Project-Based Learning model effectively improved students' critical thinking skills. The results of this study show that Project-Based Learning simultaneously with scientific literacy skills can significantly influence students' thinking skills, so it is better if the two variables can be used together to train students' critical thinking skills more optimally.

CONCLUSION

Project-Based Learning activities and Scientific Literacy Skills simultaneously affect the critical thinking skills of Physics Education students in virtual learning of the Thermodynamics class. The Scientific Literacy Ability variable partially affects the critical thinking skills variable, but there is no partial effect of Project-Based Learning on students' Critical Thinking Skills. This research implies that if the Thermodynamics lecturer wants to produce students with good critical thinking skills, the lecturer can implement a project-based learning model by practicing scientific literacy skills as part of the virtual learning process. The limitation of the results of this study is that it only occurs in the Thermodynamics course, which is held virtually at the Physics education study program at the University of Palangka Raya. Extensive research with various populations needs to be conducted to obtain general conclusions.

ACKNOWLEDGEMENTS

The author would like to thank the Faculty of Teacher Training and Education at University of Palangka Raya.

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