Profile of Students' Scientific Literacy Abilities in Higher Education on Chapter Heat and Temperature

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Abstract

Students' scientific literacy is very important to determine the extent to which students are literate about the scientific concepts that have been learned. Therefore, prospective physics teacher students must master scientific literacy to solve various problems from the real world as individuals and must interact in society and the environment as social beings. The purpose of this study was to analyze the scientific literacy skills of students of the 2019 class of physics education study program on chapter heat and temperature. This type of research used to achieve these objectives is descriptive qualitative with qualitative analysis. The subjects in this study were Lecturers in the basic physics course I and students of the 2019 class of physics education study program at Universitas Cenderawasih. Data collection techniques used in this study were tests, interviews, and documentation. The results of the research from the test instrument showed that the scientific literacy skills of physics education students class 2019 were still low. The results of the interviews strengthen the findings that there are still many physics education students of 2019 who do not have scientific literacy skills of concepts on chapter heat and temperature.

Keywords: Heat and temperature; higher education; scientific literacy; student.

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INTRODUCTION

One of the life aspects that determines the progress of a nation's life is the aspect of education (Mohr & Mohr, 2017). The demands of the 21st century make the education system in accordance with the times (Rifandi & Rahmi, 2019). In Indonesia, awareness of the importance of 21st century skills can be found in a document issued by the National Education Standards Agency in 2010 which states that "National Education in the XXI century aims to realize the ideals of the nation, namely a prosperous and happy Indonesian people, with a position respectable and equal to other nations in the global world, through the formation of a society consisting of quality human resources, namely individuals who are independent, willing and able to realize the ideals of their nation" (Rosana, Widodo, Setyaningsih, & Warno, 2020).

The quality of science overview regarding education in Indonesia related to the achievement of students' scientific literacy can be seen from one of the results of an international survey, namely the Program for International Student Assessment (PISA) conducted by the Organization for Economic Cooperation and Development (OECD). PISA survey results in the educational status of certain country. PISA results on 2018 show that Indonesian students have a low level of scientific literacy (OECD, 2018). The average randomized reading literacy score is ranked 75th out of 80 participating countries. The scientific literacy skills measured by PISA are divided into four aspects, namely, context, knowledge, competencies and attitudes. Furthermore, the results of the PISA survey revealed that the scientific literacy abilities of Indonesian children were still low, including the ability to identify scientific problems, use scientific facts, understand life systems, and understand the use of scientific tools (OECD, 2016). Indonesia is one of the participants of the Student Assessment Program (PISA). In science subjects from 2000 to 2018, Indonesia's scores were still below the international average score (OECD, 2018). This shows that the ability of scientific literacy in Indonesia is still low.

Whether we realize it or not, all activities in human life cannot be separated from scientific literacy and have a positive attitude towards science (Hallinger, Wang, & Chen, 2013). There are four categories of scientific literacy, namely science as a body of knowledge, science as a way of investigating, science as a way of thinking, and science as interactions between science, environment, technology and society (A'yun, Rusilowati, & Lisdiana, 2020).

Scientific literacy is the ability to use scientific knowledge, identify questions, and draw conclusions based on existing evidence in order to understand and make decisions regarding nature and changes made to nature through human activities (Hadi, Munawaroh, Rosidi, & Wardani, 2020). Measuring scientific literacy is very important to determine the extent to which students are literate about the concepts of science that have been learned (Holbrook & Rannikmae, 2007). Therefore, prospective physics teacher students as individuals must master scientific literacy to solve various problems from the real world, and as social beings to interact in society and their environment (Rosana et al., 2020). Understanding scientific literacy and a positive attitude towards science makes it easier for students to fulfill their life needs and makes it easier to solve real-life problems at present and in the future (Vieira & Tenreiro-Vieira, 2016).

In essence, science is understood as three aspects, namely: processes, products, attitudes, and technology. Science education of students in understanding natural phenomena or events can be carried out by scientific methods (Atmojo, Rusilowati, Dwiningrum, & Skotnicka, 2018). According to the American Association for the Advancement of Science (AAAS) in 2013, what is important in learning science is scientific literacy (Goodman, 2016). In a world filled with products of scientific work (scientific inquiry), scientific literacy is a necessity for everyone (Turner, 2018). No exception for prospective educators who are being prepared to face the challenges of the world of education in the future.

The job as an educator certainly requires high-level skills, requires people who are able to learn, reason, think creatively, make decisions, and solve problems (Chusni & Hasanah, 2018). Every citizen at various levels of education needs to have knowledge, understanding, and scientific literacy skills (Indarti, 2019). Therefore, efforts to foster a culture of scientific literacy for students in schools must of course be supported by the development of a literacy culture for educators in schools (Gormally, Brickman, & Lutz, 2012). The physics education study program as an institution that produces

high school level physics educator candidates is considered very necessary to have qualified literacy skills. Scientific literacy skills for a prospective teacher are a necessity for better science in the future (DeBoer, 2000).

Previous research found that the level of students' scientific literacy abilities in higher education is affected by media and learning strategies (Gormally et al., 2012; Saputra, Al Auwal, & Mustika, 2017; Vieira & Tenreiro-Vieira, 2016). Other study found that even though some teachers have low level mastery of science, but the overall mastery of science teachers shows the middle category. Teachers' scientific literacy in the low categories was 20%, in the medium category was 65%, and in the high category was 15% (Rubini, Ardianto, Pursitasari, & Permana, 2016). Based on the explanation above, it can be said that research by analyzing scientific literacy skills for prospective teacher students is very important to do as a preliminary research for the development of further research related to the scientific literacy of physics education students. Therefore, this study aimed to conduct analysis of the scientific literacy skills of 2019 physics education students as prospective teacher on chapter heat and temperature. Based on the background of the problem above, the formulation of the problem of this research is how the scientific literacy ability of 2019 class of physics education students on the concept of temperature and heat is. The focus of the problem in this research is the ability of scientific literacy according to OECD which includes science knowledge and competence in physics education students of class 2019.

METHOD

Research Design

The focus of this research is to analyze scientific literacy skills. This type of research is qualitative descriptive with qualitative analysis. This research will describe the measurement of the science literacy skills of physics education students class of 2019 as future physics teacher candidates.

Population and Samples

The location of this research is in the physics education study program, Faculty of Teacher Training and Education, Universitas Cenderawasih. The implementation time is for 3 months, starting from December 2020 to February 2021. The subjects in this study were Lecturers in the basic physics subject I and students of the 2019 class of physics education study program, Universitas Cenderawasih. Respondents in this study were students of the 2019 class of physics education study program who were active in the lecture process whose grades in basic physics I had passed and a lecturer who taught basic physics subject I. Respondents were selected by purposive sampling technique.

Data Collecting Technique

Data collection techniques used in this study were tests, interviews, and documentation. Giving tests include posttest according to the indicators and objectives developed by the researcher. The test is used to measure students' scientific literacy abilities in higher education. The test framework given to students is shown in Table 1 (OECD, 2018).

Table 1. Science Literacy Ability Test Framework.

Cognitive Aspect		Competences Aspect		
		Identifying Scientific Issue	**Explaining Scientific Phenomena**	**Utilizing Scientific Evidence**
Temperature	Thermometer & temperature scale	1, 4	3	2
	Expansion of solids	-	-	5, 6
	Liquid expansion	-	-	7
Heat	Heat capacity	-	-	8
	Specific heat	9, 18	12	13
	Black Principle	11	10	19
Heat Transfer	Conduction	16	17	-
	Convection	15	20	-
	Radiation	-	-	14

The interview used in this study was a free guided interview or an unstructured interview, where the researcher brought guidelines that only outline the things to be asked. The sample is a lecturer who teaches basic physics material I. Interviews are used to collect qualitative data from students and lecturers. Documentation aims to obtain data directly from the research site, including relevant books, regulations, activity reports, photographs, documentary films, research relevant data.

Data Analysis Technique

The data analysis technique used in this research is descriptive qualitative as proposed (Huberman & Miles, 2002). Qualitative descriptive analysis is carried out in three ways, namely data reduction, data presentation and drawing conclusions or verification of the three components as a mutually exclusive unit. related and the process repeats itself interactively and occurs during or after data collection occurs. After the data from the field has been collected using the data collection method above, the researcher will process and analyze the data using descriptive-qualitative analysis, without using quantitative techniques.

RESULTS AND DISCUSSION

Student Test Results for Cognitive Aspects

This research refers to the ability of scientific literacy according to the analytical framework of the latest OECD and PISA test (OECD, 2016, 2018). The grid is based on scientific literacy indicators presented in Table 1. namely aspects of competence and aspects of knowledge. The results of this study indicate that the problem of scientific literacy ability in the concept of temperature and heat is still low. Researcher divided the data based on three levels. The blue graphic is the lowest score, the red graphic is mean score, and the green graphic is the highest score. Figure 1 shows a complete graph of the student cognitive test scores.

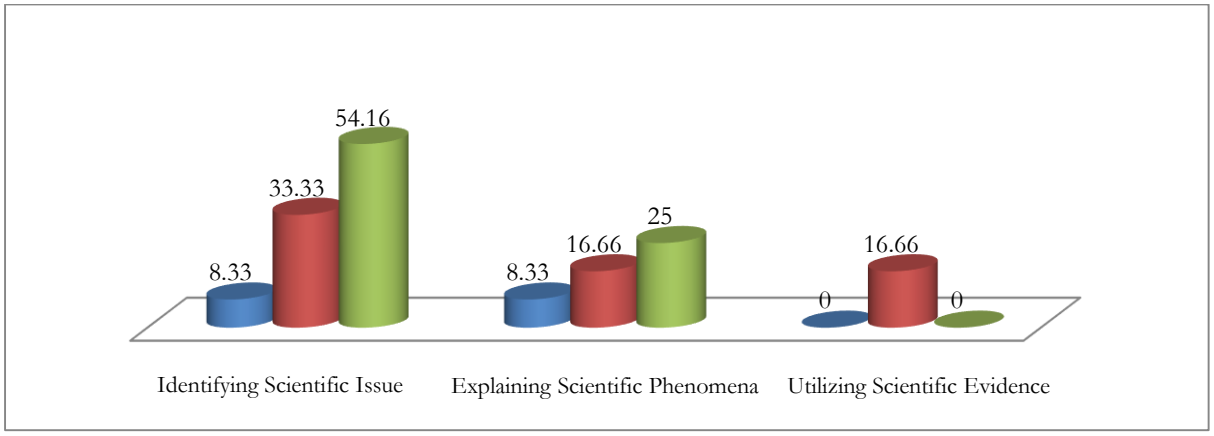

Figure 1. Student Test Results for Knowledge Aspects.

Figure 1 shows the cognitive scores of students which contain scientific literacy skills in competency and knowledge aspects. The average percentage of competency aspects with indicators of identifying scientific issues aspect, explaining scientific phenomena aspect, and utilizing scientific evidence aspect was 33.33%, 16.66%, and 16.66%.

Examples of Student Test Answers

On January 27, 2021, the researcher conducted a study to see the scientific literacy abilities of the 2019 class of physics education students, the researcher gave 20 multiple choice test questions on temperature and heat. A total of 12 students who did the given test questions. Of the 20 items, there were several questions where many students chose the wrong answer. The questions consist of numbers 2, 4, 6, 10, 13, 14, and 16, each of which contains aspects of competence with indicators of identifying scientific issues, explaining scientific phenomena, and using scientific evidence.

Figure 2 is an example of student results that contain scientific literacy skills in the competency aspect with indicators identifying scientific issues in the knowledge aspect, with the concept of a temperature scale.

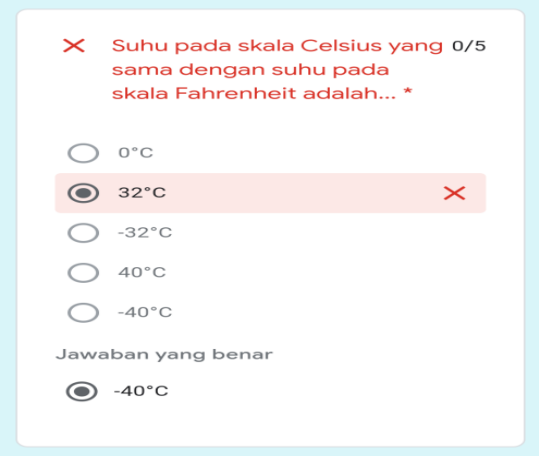

Figure 2. Examples of student results on competency aspects identifying scientific issues on the concept of a temperature scale.

Figure 3 is an example of student results that contain scientific literacy skills in the competency aspect with indicators explaining scientific phenomena in the aspect of knowledge, in the Black Principle concept.

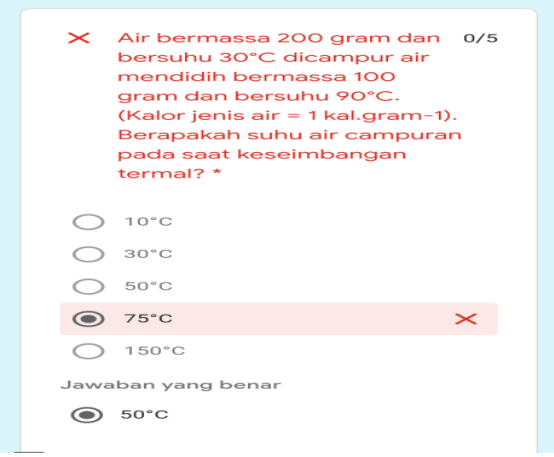

Figure 3. Examples of student results on competency aspects explaining scientific phenomena in the Black Principle concept.

Figure 4 is an example of student results that contains scientific literacy skills in the competency aspect with indicators utilizing scientific evidence on the aspect of knowledge, with the concept of a temperature scale.

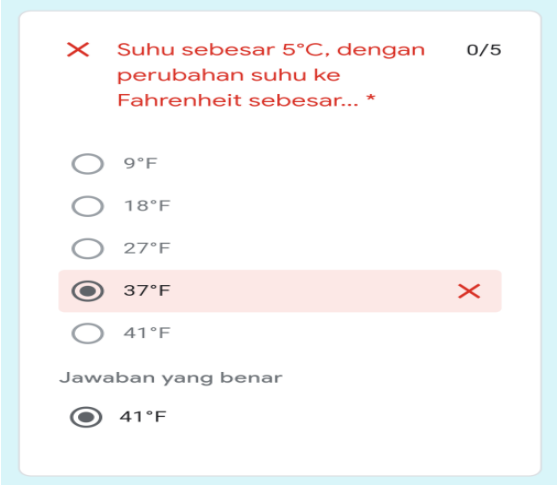

Figure 4. Examples of student outcomes in competency aspects using scientific evidence on the concept of a temperature scale.

Results of Interviews with Students

To add information in analyzing student literacy skills, researchers conducted interview techniques. Interviews were conducted with 10 students and 1 lecturer in basic physics subject I. The following are the results of interviews from 10 student respondents who were selected and ready to be interviewed related to the concepts of temperature and heat. The ten students interviewed were: DK, HJ, YB, CS, FA, WD, SR, MD, NL, and MS. Researchers conducted interview and documentation techniques to obtain data from students related to the test questions they had worked on.

To find the right temperature the observer had to use a measuring instrument. According to the ten students who were interviewed said that the measuring instrument used to measure temperature was a thermometer. Researchers conducted interview and documentation techniques to obtain data from students related to the test questions they had worked on. According to DK (respondent 1) there are 3 kinds of scale on the thermometer scale, namely Celsius, Fahrenheit, Reamur. According to DK, the calculation of degrees Celsius to degrees Fahrenheit by adding a value of 32.

> "The calculation for the conversion from Celsius to Fahrenheit uses a comparison formula. The ratio is 4/5 times the known temperature. That's all I remember."

In measuring instruments there are properties of how it works in order to know the

temperature. According to DK, the nature of the way the thermometer works is like measuring high temperatures or hot or cold. An object whose size suddenly increases because it is affected by high temperature changes. According to HJ, an object is said to be expanding due to the influence of temperature which interacts outward so that it is said to be expanding.

> "I think that the object will expand because the temperature will interact outward and the temperature on the object will decrease so that it is said to be expanding."

In the heat material there is such a thing as specific heat. In this interview to see what specific heat they know. DK was unable to provide a response regarding the definition of specific heat. According to HJ, specific heat is influenced by a mass, latent heat, specific heat, and temperature.

> "What I know about specific heat is influenced by a mass, melting heat, ice heat, heat and temperature."

When asked about heat transfer, FA, WD and SR did not provide answers. According to MD, heat transfer is the transfer of hot or cold energy from one place to another.

> "Heat transfer is transferring of hot or cold energy from one place to another."

In the heat transfer material there are three types of heat transfer, namely by conduction, convection, and radiation and in this interview he was asked to mention each example of the three types of heat transfer According to MD, an example of conduction is when we burn iron, the iron will feel hot, for example convection is the heat of the campfire to our bodies. An example of radiation is the heat of the sun drying clothes beneath the sun.

> "An example of conduction is burning iron and the iron will feel hot. An example of convection is like the heat of a campfire to our bodies. Radiation is like the heat of the sun drying clothes beneath the sun."

The last point asked during the interview is about thermal equilibrium. According to CS, thermal equilibrium is like boiled water which initially has low temperature, after boiling its temperature rises.

> "The thermal equilibrium is like water that we cook at low initial temperature and when the water boils its temperature rises or increases."

Based on the results of the interviews from the ten students above, it can be seen that there are some students who have not been able to mention and explain the concepts of temperature and heat that were asked in the interview. This shows that there are still many students of physics education class 2019 who do not yet have scientific literacy skills in the concepts of temperature and heat.

Results of Interviews with Lecturer

After interviewing students regarding the cognitive tests they had done, the researcher interviewed the lecturer in the basic physics subject 1. The lecturer said that the strategies used in teaching physics were cooperative learning and direct instruction.

> "The strategy used in learning basic physics 1 here we use a cooperative learning model and a direct learning model. For the approach that we are using here, we have not done the scientific approach yet. Both the following for the learning method we still use the lecture method, the discussion we still use often. For demonstrations it is rarely or not used at all."

Students are already enthusiastic in participating in learning physics courses. However, the mean learning outcomes are still low. According to the informants, students still have a low understanding of physics concepts.

> "Understanding the concept in learning physics I for class 2019 is understanding the concept to the ability of students here. There are indeed many high and moderate categories students so that the conceptual understanding of students here is good and for those who are lacking there are some but not so much."

When asked about the competence of student achievement in physics education and its relation to scientific literacy, the resource person answered that only a few students were able to use their scientific competences.

> "For students, identifying scientific issues students can explain scientific feonomena as well and can use scientific evidence as

well as they can, but only a few people who have the ability and high competence of their friends who better master scientific competences, namely identifying, explaining and using scientific evidence."

The results of the interview obtained from the lecturer in basic physics 1 showed that in learning basic physics 1 all students were very enthusiastic in participating in the learning. For facilities to support learning there are no obstacles, but the ones that become obstacles are the different abilities, infrastructures, and economic backgrounds of students.

Discussion

Aspects of scientific literacy consist of context, knowledge, competence, and attitudes (OECD, 2016, 2018). The PISA assessment is made so that students can understand that science has particular value for individuals and society in improving and maintaining the quality of life and in the development of public policies (Bieber & Martens, 2011). In this study, the aspects of scientific literacy ability that were measured were aspects of competence and scientific knowledge.

Based on Figure 1, the science literacy results of physics education students class 2019 are still low. This shows that the literacy skills of 2019 class of physics education students in understanding the concepts of temperature and heat are still low. In the competency aspect with indicators identifying scientific issues, the lowest result is the concept of conduction heat transfer. In the indicator explaining scientific phenomena, the lowest result is the concept of Black Principle and heat transfer by convection. For indicators using scientific evidence, the lowest results of students' score are on the concept of the temperature scale and specific heat.

Samples of interviews were based on Huberman and Miles to support data triangulation (Huberman & Miles, 2002). Interviews with students and lecturer showed differences in students' cognitive abilities. Judging from the cognitive abilities of students, who have abilities above average or high are around 3 to 5 people, students who have moderate abilities were around 7 to 10 people, and the rest are in the low category. In understanding the concept, students in learning basic physics I according to their respective abilities were categorized in high and medium, while students with low understanding were only a few. Students' scientific competence in identifying scientific issues, explaining scientific phenomena, and utilizing scientific evidence are not achieved optimally. Not all students can achieve those competences, only a few students who have a high level of ability have mastered competences in identifying scientific issues, explaining scientific phenomena, and utilizing scientific evidence. These findings are supported by previous research related to scientific literacy. Kusumah conducted a research to apply scientific approach to students and he found that students' scientific literacy was low due to the lack of scientific attitude (Kusumah, 2019). It is also supported by Budiarti who found that students' scientific literacy in Papua on concept motion of living things is low. The same reasoning is in line as if students do not own android smartphone with internet connection (Indah Slamet Budiarti & Tanta, 2021). Scientific literacy due to scientific approach as learning strategy is needed to achieve by students to master conceptual understanding. High scientific literacy can lead to better learning outcome (Indarti, 2019; Rini, 2020).

In basic physics learning 1, a scientific approach has been applied but not completely, the model used is only two models, namely cooperative learning and direct learning and lecture and discussion methods. The low ability of scientific literacy is due to the fact that the learning process in lectures has not fully involved the scientific process. Different backgrounds of student abilities also lead to low scientific literacy skills, because not all students have abilities at the same level. Students with low economies cause limited facilities and infrastructure such as Android phones, laptops that support science literacy-based learning.

Below the researcher discussed about three competences of scientific literacy based on findings in Figure 2, 3, and 4.

Identifying scientific issues is recognizing issues that may be investigated scientifically, identifying key words for scientific information, and recognizing the characteristics of scientific investigation (OECD, 2018). Figure 2 shows that students were unable to identify the scientific issue of determining the same temperature on the Celsius scale and the Fahrenheit scale. Problem number 4 is shown in Figure 2. Students are expected to be able to determine the same temperature between the

Celsius scale and the Fahrenheit scale, but many students cannot determine the same temperature from the two scales because the correct answer to question number is -40ºC. It can be said that many students do not yet have scientific literacy skills in identifying scientific issues, so they cannot determine the same temperature from the two scales, namely the Celsius scale and the Fahrenheit scale. This finding is supported by previous research regarding on how students hold conceptual consistency on thermal heat and temperature concepts (Indah Slamet Budiarti, Suparmi, Sarwanto, & Harjana, 2017).

Explaining scientific phenomena is applying scientific knowledge in a given situation, describing or interpreting phenomena and predicting change, identifying appropriate descriptions, explanations, and predictions (OECD, 2018). Based on Figure 3, it can be concluded that students are not able to explain scientific phenomena about the Black Principle concept. In question number 10, which can be seen in Figure 3, the correct answer is 50ºC. In this question, students are expected to be able to determine the correct final temperature of the mixture. However, it can be seen in the question that students are not able to explain scientific phenomena by interpreting the temperature of mixed water in thermal equilibrium because students do not have scientific literacy skills on the Black Principle concept. This finding is supported by previous research regarding on how students have better conceptual understanding on Black Principle concepts (Winarti et al., 2017).

Utilizing scientific evidence is interpreting scientific evidence and drawing conclusions, providing reasons to support or rejecting conclusions and identifying assumptions made in reaching conclusions, communicating conclusions related to evidence and the reasoning behind conclusions and making reflections based on the social implications of scientific conclusions (OECD, 2018). In Figure 4, it can be seen that students are not able to use scientific evidence shown from the picture which contains question number 2 because they chose the wrong answer. In question number 2 which is seen in Figure 4, students are expected to understand the concept of the scale on the thermometer. Students apparently do not understand the concept of the temperature scale so they cannot change the Celsius scale to the Fahrenheit scale and the correct answer to question number 2 is 41ºF. It is supported by previous research regarding on how students have difficulties on determining the temperature scale (Alwan, 2011).

Three examples of student answers based on the questions above show that physics education students of class 2019 do not have high scientific literacy skills. This is due to those who are not familiar with scientific literacy-based learning (Schraw, Crippen, & Hartley, 2006). They also do not fully understand scientific literacy-based learning though they were taught about the heat and temperature concepts. Lack of supporting facilities to achieve scientific literacy ability causes students to not master scientific literacy skills, so that their scientific literacy skills are still low (Indah Slamet Budiarti & Tanta, 2021). Apparently, the findings are in line with the other previous researcher who focused on Papua learning implementation. It turns out that the educational status of Indonesia in Papua is not optimally applying scientific literacy during the teaching and learning process (Budiarti, Suparmi, Sarwanto, & Harjana, 2020; Ibrahim, Sutawi, & Jayus, 2013; Purbowo, Boy, & Budiarti, 2020; Supriyadi, Palittin, & Martini, 2008).

CONCLUSION

There are still many students of physics education class 2019 who do not have scientific literacy skills. This can be seen from the results of the test of scientific literacy skills in the form of 20 items that have been done by physics education students class 2019. The test questions cover aspects of knowledge and aspects of competence according to OECD (2014). In the competency aspect, there are three indicators, namely identifying scientific issues, explaining scientific phenomena, and using scientific evidence. The average percentage of competency aspects with indicators of identifying scientific issues, explaining scientific phenomena, and using scientific evidence is 33.33%, 16.66%, and 16.66%, respectively. The low ability of scientific literacy is due to the fact that the learning process in lectures has not fully involved the scientific process. Different backgrounds of student abilities also lead to low scientific literacy skills, because not all students have abilities at the same level. Another thing is the influence of the low ability of scientific literacy due to limited supporting facilities and infrastructure in science literacy-based learning.

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