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Scientific and Information Literacy of High School Students

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Abstract: This study aims to analyze the level of scientific, information literacy, and determine the relationship of scientific and information literacy. This quantitative descriptive survey has a sample of 145 high school students, selected by random sampling. Scientific and information literacy instruments have been validated by the experts and tested on 25 students who have studied Bacteria. The majority of scientific and information literacy are at the developing level. There is a positive relationship between scientific and information literacy for high school students. Based on these results, efforts are needed to empower scientific and information literacy for high school students by applying innovative learning models.

Key Words: scientific literacy; information literacy; high school students

Abstract: Penelitian ini bertujuan untuk menganalisis tingkat literasi sains, literasi informasi, dan mengetahui hubungan literasi sains dan literasi informasi. Penelitian deskriptif kuantitatif survei ini mengambil sampel 145 siswa SMA yang dipilih dengan random sampling. Pengumpulan data dengan instrumen literasi sains dan literasi informasi yang telah divalidasi oleh validator dan diujikan pada 25 siswa yang telah mempelajari materi Bakteri. Mayoritas literasi sains dan literasi informasi berada pada tingkat *developing*. Terdapat hubungan positif antara literasi sains dan literasi informasi siswa SMA. Berdasarkan hasil tersebut, diperlukan upaya peningkatan literasi sains dan literasi informasi siswa SMA misalnya dengan penerapan model pembelajaran inovatif.

Kata kunci: literasi ilmiah; literasi informasi; siswa SMA

INTRODUCTION

The 21st-century is known as the century of knowledge because knowledge is increasingly developing with technological developments in various fields (Yelland, 2006). On the other hand, socio-science problems arise as a negative impact of technological developments (Zeidler & Nichols, 2009). The challenges of the 21st-century require innovative solutions that are grounded in scientific thought and scientific discovery (OECD, 2016a). Science educators have an urgency to turn students into scientific literates (Bybee, McCrae, & Laurie, 2009) and solve socio-science problems scientifically through learning (Hancock, Friedrichsen, Kinslow, & Sadler, 2019; Tidemand & Nielsen, 2017; Zeidler & Kahn, 2014).

The 21st-century, apart from being known as the age of knowledge, is also known as the information age which is marked by the ease and abundance of scientific information from various sources such as the internet and social media. 21st-century learning emphasizes students as the center of learning so that students seek, process, and convey information independently, not just receiving from the teacher. The availability of various sources of information needs to be filtered so that information taken could develop the students' potential (Virkus, 2011). Therefore, students must have information literacy to determine the available information based on reliable data and information drawn from credible research (Ministry of Education and Culture, 2017a).

Scientific literacy has entered a new era in the 21st-century (Chen, 2019). The new era of scientific literacy can be seen from the emergence of changes in the definition of scientific literacy. Scientific literacy was introduced by Paul De Hart Hurd, a science education expert in an article entitled *Science literacy: It's meaning for American schools*. Hurd(1958) interpreted scientific literacy as an understanding of science and its application in daily life. A human being with scientific literacy is not only being able to read, write, and communicate scien-

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tific texts(Norris & Phillips, 2003) but also being able to use scientific concepts meaningfully(Rahayu, 2016), distinguishing scientific problems from unscientific problems, using scientific evidence as a basis in constructing solutions to scientific problems (Ministry of Education and Culture, 2016b) and applying scientific knowledge by interpreting information critically using logical evidence and making scientific decisions with evidence (Majima, 2012).

Program for International Students Assessment (PISA) defined scientific literacy as the ability to engage with issues related to science and scientific ideas as a reflective society (OECD, 2016b). There are three indicators of scientific literacy based on the OECD (2016), (1) explaining scientific phenomena, requiring students to recall scientific knowledge and making predictions about scientific phenomena, (2) evaluating and designing scientific investigations, requiring students to identify errors in research designs, for example determining and measuring wrong factors, and (3) interpreting data and providing scientific evidence require students to identify conclusions from observational tables, graphs, or other forms of data. Scientific literate society could solve problems scientifically (Kobori et al., 2016) and make the right decisions (Yacoubian, 2018).

Scientific literacy plays a role in determining the progress of the nation by improving the quality of human resources and increasing the standard of living (Ministry of Education and Culture, 2017b). Several studies have shown a positive relationship between scientific literacy and higher-order thinking skills, in the form of critical thinking (Kusumastuti, Rusilowati, & Nugroho, 2019), creative thinking and scientific attitude (Rusdi, Sipahutar, & Syarifuddin, 2017), and science process skills (Gurses, Gunes, Barin, Eroglu, & Cozel, 2015; Handayani, Adisyahputra, & Indrayanti, 2018). Integrated scientific literacy measurement is also related to information and data processing(Gormally, Brickman, & Lutz, 2012) with scientific literacy indicators in the form of (1) recognizing and analyzing the use of investigative methods that lead to scientific knowledge and (2) being able to organize, analyze, and interpret quantitative data and scientific information.

Information literacy was introduced by Zurkowski in 1974 and defined information literacy as the ability to use techniques and skills for various information tools as well as the main source in developing information solutions to a problem. (Thomas, 2004). Initially, information literacy was identical to the library sector(Breivik & Gee, 1989; Homann, 2001)especially regarding library instruction, bibliographic instruction, and educational users / readers. The definition of information literacy evolves from gathering information to communicating information and ideas(Catts & Lau, 2008).

Information literacy skills begin with realizing the need for information according to the topic (AACU, 2016). This need is continued by identifying and finding information, evaluating information critically, and then organizing and integrating information into existing knowledge. Various information that has been managed is utilized and communicated in an effective, legal, and ethical manner (UNESCO, 2003). The Association of College & Research Libraries (ACRL) defined information literacy as a person's skills in finding information, choosing appropriate information sources, assessing / evaluating information, filtering necessary information, and using information ethically and effectively. Based on this definition, information literacy is the ability needed to select, process, evaluate information available for ethical use (ACRL, 2010)

Information literacy plays a role in improving the quality of citizens. Information literacy is a requirement for citizens to participate in the information society and basic human rights regarding lifelong learning. Prague Declaration (UNESCO, 2003) and the Alexandria Declaration (UNESCO, 2005) are evidence that shows the importance of information literacy (Ministry of Education and Culture, 2016a). Various information and efforts to criticize it can open students' mindset and guide students towards a better awareness (Antoro, 2017).

Several previous studies reported the results of scientific literacy (Ariyanti, Ramli, & Prayitno, 2016; Mukti, Yuliskurniawati, Noviyanti, Mahanal, & Zubaidah, 2019; R, Rinanto, & Ramli, 2019; Rahmadani et al., 2018; Rizkita, Suwono, & Susilo, 2016; Mahanal, Zubaidah, and Setiawan, 2019) and information literacy (Anwar, Rizal, & Saepudin, 2015; Arsyadi & Prasetyawan, 2017; Latifah & Husna, 2016; Novitasari, Wulan, & Utari, 2018), but no research explains the relationship between scientific and information literacy of high school students specifically. Research needs to be done to find out how scientific and information literacy of high school students are so that they can determine the right strategy to facilitate and improve their literacies. This research was conducted to achieve the objectives based on the following problem formulations (1) What is the level of scientific literacy of SMA students in Batu? (2) What is the information literacy level of SMA students in Batu? And (3) How is the relationship between scientific literacy and information literacy among high school students in Batu?

METHOD

This survey research was conducted to analyze the level of scientific and information literacy of high school students and the relationship between scientific and information literacy. The population of this study was high school students in Batu City, East Java, Indonesia. The sample was selected by random sampling to obtain 145 students from SMAN 1, SMAN 2, and SMAN 3 Kota Batu.

Scientific literacy was measured by 6 description questions on the Bacteria material. Essay questions were prepared based on literacy indicators (1) explaining scientific phenomena scientifically, (2) designing and evaluating methods of inquiry that lead to scientific knowledge, (3) organizing, analyzing, and interpreting quantitative data and scientific information adapted from Gormally, Brickman, and Lutz (2012) and the OECD (OECD, 2016a).

Information literacy was measured by a multiple-choice questionnaire consisting of four options. All items were under the ACRL information literacy indicator (ACRL, 2010)namely seeking information, selecting appropriate sources of information, assessing/evaluating information, filtering necessary information, and using information ethically and effectively. The results were then analyzed and categorized based on Table 1.

Table 1. Criteria for Levels of Scientific and Information Literacy

Criteria	Score
Emerging (Level 1)	$3.33 < x \leq 4.00$
Developing (Level 2)	$2.33 < x \leq 3.33$
Proficient (Level 3)	$1.33 < x \leq 2.33$
Advanced (Level 4)	$0.00 < x \leq 1.33$

Modified from Kurniasih and Sani (2014)

The scientific and information literacy instruments have been validated by material and education experts. The validity and reliability of the instruments were also tested empirically. The questions that have been developed were tried out on 25 students who had studied bacterial material in the tenth grade. The trial results were then analyzed to determine validity and reliability. The validity results can be seen in the table and the reliability results can be seen in Table 2.

Based on the results in Table 2 and Table 3, the instruments developed were valid and reliable as a means of collecting scientific literacy data on bacteria material for high school students. The results of the students' answers were analyzed using the scientific literacy rubric which was adapted from Gormally, Brickman, & Lutz(2012)and OECD (2016). Students' answers were scored 1-4 according to the rubric shown in the table. The results of the analysis of scientific and information literacy were then categorized according to Table 4.

Table 2. Instrument Validation Results

Item	Pearson Correlation	Sig. (2-tailed)	Interpretation
Number 1	0.418	0.038	Valid
Number 2	0.571	0.003	Valid
Number 3	0.617	0.001	Valid
Number 4a	0.652	0,000	Valid
Number 4b	0.641	0.001	Valid
Number 5	0.634	0.001	Valid
Number 6a	0.720	0,000	Valid
Number 6b	0.652	0,000	Valid

Table 3. Instrument Reliability Results

Cronbach's Alpha	Total N
0.75	8

The data in this study were analyzed using the help of data processing software. The data obtained were tested for normality first. The relationship between scientific and information literacy was analyzed for correlation.

RESULTS

The majority of high school students' scientific literacy in Batu were 74.4% or in the developing category. The high school students' information literacy was 42.8% or in the developing category and the other 41.4% was in the Emerging category. The scientific and information literacy data of students obtained could be seen in Table 5.

Table 5. Results of Scientific and Information Literacy

Criteria	Percentage (%)	
	Scientific Literacy	Information Literacy
Emerging	17.9	41.4
Developing	74.4	42.8
Proficient	7,6	15.8
Advanced	0	0

Table 6 illustrated the correlation between scientific and information literacy. There was a positive correlation between scientific and information literacy. The level of the relationship between the two variables showed that the Pearson correlation value was 0.579, meaning that it had a strong and positive relationship, the value

Table 4. Scientific Literacy Rubric

Indicator	Subindicator	Score	Description
Explaining scientific phenomena in a scientific manner	Describe scientific knowledge	1	Not being able to recall scientific knowledge and apply scientific knowledge appropriately
		2	Be able to recall but not able to apply scientific knowledge appropriately
		3	Be able to recall scientific knowledge and apply scientific knowledge in general
		4	Be able to recall scientific knowledge and apply scientific knowledge appropriately
	Identify valid scientific arguments	1	Not being able to compile claims and evidences
		2	Write claims correctly but evidences do not support claims
		3	Be able to relate claims to evidences but do not reveal reasons linking the two
		4	Be able to properly relate claims to evidences
Designing and evaluating methods of inquiry that lead to scientific knowledge	Design scientific investigations	1	Not being able to formulate a scientific way of exploring questions
		2	Formulate ways of exploring questions in a general and concise manner
		3	Formulate ways of exploring questions using scientific methods in general
		4	Formulate how to explore questions using scientific, detailed, and precise methods
	Evaluate scientific actions based on the use and avoiding misuse of scientific information	1	Not being able to identify valid and ethical scientific actions Not being able to identify the proper use of science
		2	Be able to identify valid and ethical scientific actions Be able to identify the proper use of science in a simple manner
		3	Be able to identify valid and ethical scientific actions Be able to identify specific uses of science
		4	Be able to identify valid and ethical scientific actions Be able to identify the appropriate use of science in a complex and detailed manner
Organizing, analyzing, and interpreting quantitative data and scientific information	Create a graphical representation of data	1	Not being able to convert narration into graphical form such as tables or graphs
		2	Arrange graphical representations such as tables or graphs but not complete
		3	Arrange graphica representations according to components but less communicative
		4	Arrange graphic representations according to components and communicative
	Interpret a graphical representation of the data	1	Interpret and communicate data graphically using language that is less communicative and inaccurate
		2	Interpret and communicate data graphically using communicative language but have not been able to make the right interference
		3	Interpret and communicate data graphically using communicative language and make simple interference
		4	Interpret and communicate data graphically using communicative language and make appropriate interference
	Understand and interpret basic statistics	1	Not being able to understand the statistical need to measure data uncertainty
		2	Understand the statistical need to simply measure data uncertainty
		3	Understand the statistical need to measure data uncertainty in general
		4	Understand the statistical need to measure data uncertainty in detail and complexity
	Arrange interpretations, predictions, and conclusions based on quantitative data	1	Not being able to use quantitative data to construct interpretations, predictions, or conclusions
		2	Be able to use quantitative data to make interpretations, predictions, and conclusions but not complete
		3	Be able to use quantitative data to compose interpretations, predictions, and conclusions but not in accordance with the problem formulation
		4	Be able to use quantitative data to formulate interpretations, predictions, and conclusions appropriately according to the formulation of the problem

adapted from Gormally, Brickman, & Lutz (2012) and the OECD (OECD, 2016a)

Table 6. Correlation of Scientific and Information Literacy

r (Pearson Correlation)	*Sig. (2-tailed)*	*r square*
0.579	0,000	0.335241

of R Square, which proved that scientific literacy was influenced by information literacy.

DISCUSSION

Students' Scientific Literacy Level

The lowest level of scientific literacy, namely the Emerging level, was still found in 17.9% of students. At the Emerging level, students were unable to identify ethical scientific actions and did not apply science appropriately. The following were the examples of student questions and answers based on each category. Question:

"Oil spills have occurred in Balikpapan Bay in 2018 and off the coast of the Java Sea in 2019. Oil spills can damage marine ecosystems widely and last a long time. The oil that has a high density can cover the surface of the expanse and interfere with the photosynthesis of marine life because sunlight is blocked by the oil. In the long term, the mangrove, seagrass, and coral reef ecosystems in the area can die. As a student who cares about the environment, explain what solutions you think can solve these problems! "

Examples that are categorized at the Emerging scientific literacy level.

Accidents that have occurred cannot be fixed, therefore the government should be more careful and investigate the consequences of this incident, such as checking the condition of pipes in the sea every month, whether they are okay or not. -RNA students

Demand protests against the authorities to address the problem and follow up with the perpetrators. -RHI students

The process to the authorities regarding the oil spill / prosecute the person who spilled oil around Indonesian waters. - MRA students

The answers from students indicated a lack of scientific solutions to solve problems regarding the oil spill and tended to blame the situation. The answers given did not indicate critical thinking even though one of the components of scientific literacy was being able to think critically and evaluate scientific claims and evidence (Majima, 2012).

The majority of students were at the Developing Level. At this level, they have been able to identify ethical scientific actions and apply science as a solution to solving problems. The following was an example of students' answers categorized at the scientific literacy Developing level.

Using hydrocarbon bacteria. So, if the bacteria are in the sea, there is a need for nutrients, for example, phosphorus and nitrogen. The artificial bacteria are released into the sea, and then the bacteria will eat the oil, and the plankton will eat the bacteria, and so on so that the food chain in the ocean continues and breaks down the oil more efficiently. - NAI students

In my opinion, the right solution is to cultivate a more efficient artificial hydrocarbon bacteria (Alcanivorax borkumensis). These bacteria degrade petroleum products in soil and water. - SNI students

Cultivate bacteria to clean up oil spills so it would not damage anything in the water. - FWR students

The answers given by students have used science as a solution to the oil spill problem, but they understood the phenomenon and the solution simply.

Only 7.6% of students included in the Proficient category. At this stage, students have been able to identify scientific actions precisely and specifically. The following was an example of student answers in the Proficient category.

Accelerate the growth and reproduction of Alcanivorax borkumensis. These bacteria usually appear in the sea or when there is an oil leak. First taking samples of polluted water from the sea and cultivating bacteria from seawater in the laboratory and then the water is sprayed on the contaminated water to stimulate the bacterial to absorb the oil. The researchers added phosphorus and nitrogen to the mixture. The researchers supplied the nutrients directly to the bacteria so they could break down the oil even more efficiently.–SN student

Students in the Proficient category have been able to find appropriate solutions but were less complex. In fact, there was no student found in the highest category, the Advanced category. None of the students' answers indicated the proper use of science in its complex and detailed manner. Scientific literacy competencies not only explaining knowledge of scientific concepts and theories but also knowledge of procedures and practical matters related to scientific investigations in detail (OECD, 2016a).

Various factors that cause low scientific literacy. Students were not familiar with scientific literacy questions consist of scientific texts that require skills such as making conclusions, drawing conclusions, showing chronological time sequences, forming hypotheses, cause and effect relationships(Karademir & Ulucinar, 2017). Another cause of low scientific literacy was students' lack of understanding of terms in scientific investigations and more frequent memorization of material compared to practicum activities (Rusilowati et al., 2018) so they were less able to think critically. Low scientific literacy could be indicated by students not connecting phenomes in everyday life with learning material(Putri, Yuliati, & Hidayat, 2019).

Student Information Literacy Level

The level of student information literacy was not much different from students' scientific literacy. The majority of students, 42.8%, were in the Developing category. As many as 41.4% were still in the lowest category of information literacy and only 15.8% were in the Proficient category. Similar to the level of scientific literacy, there were no students who had information literacy in the Advanced category.

The difficulty of students in information literacy lied in the indicators of accessing the information needed effectively and efficiently. When students were asked the question "If you were asked to determine information about the role of bacteria in life from various sources, which literary source do you use often?" with the choice of answers (a) browsing on google and choosing the top-recommended blogs, (b) interviews with sources around us, (c) research books and journals, and (d) official websites of the government or institutions as sources of information, only 15,7% of students who answered research books and journals.

These results indicated that students were less able to find valid and reliable sources of information. In line with the results of this study, Malliari et al (2017) revealed that 26.3% of high school students in Greece use journals as a source of information and 73.6% use the internet. Even though students have been introduced to specific websites such as SciFinder and database libraries, students still rely on Google as their primary search (Shultz & Zemke, 2019).

Students also could not effectively select information and sources to use for a specific purpose. Students were asked the question "You have an assignment to make a resume on Protista material. How do you use the information provided to complete the task? " with the answer choices (a) I will use the information according to the strategy that I have compiled and choose the actual information, (b) I will paraphrase the information I have analyzed and use the relevant information, (c), I will write down all the information that I think is right from various literary sources, and (d) I will select the most updated information from blogs that appear in top searches while browsing. Based on the students' answers, only 21.4% answered correctly.

In general, students were at the Developing level and needed to be improved. Various factors influence the low level of information literacy. The cause of low information literacy began with low reading interest (Ministry of Education and Culture, 2016; Rahmawati, Wulan, & Utari, 2019). Reading habits could develop skills for filtering, criticizing, and communicating information to other students (Tarunasena et al., 2018). The majority of teenage students often read various information by accessing the internet, but the information accessed was not necessarily valid and reliable. Students spent more time on social media (Lenhart, 2015).

Relationship between Scientific and Information Literacy

The relationship between scientific and information literacy showed a positive correlation with an r-value of 0.579. The results of this study were supported by research conducted by Podgomik, et al (2017)which showed similar results. The relationship between information and scientific literacy can be learned when students conduct investigations as a process that focuses on open-ended questions. Students conducting scientific research need to know how to develop hypotheses or problem formulations that address gaps in knowledge, develop appropriate research designs to answer problem formulations. Students also need to understand research design not only for their own research but also so that students can understand and evaluate other people's research (Berman, 2017).

Basic, scientific, technological, visual, and cultural literacy can be considered as specific competencies that fall under the information literacy umbrella. Information literacy should be considered as a container concept, which refers to the competence to recognize the need for information and to meet information needs for survival, self-actualization and development (Boekhorst, 2003). Thus, the higher the information literacy, the higher the scientific literacy (Podgornik et al., 2017). Scientific literacy is concerned with the general ability to find and use the information to understand science in a larger context; this general ability is usually referred to as information literacy (Berman, 2017).

The development of scientific literacy is parallel to information literacy, moving from a standards-based approach to a more critical approach. There are overlapping content and the potential to mutually reinforce these two literacies (Kuglitsch, 2018). Information literacy and scientific literacy begin with generating prior knowledge and end with communications of results/ findings, generation of hypotheses in science versus planning search strategies, evidence search for repeated search execution, and construction of scientific arguments for information evaluation. Introduction to information literacy will support cognitive skills required for successful problem solving, and for students' ability to distinguish between evidence-based scientific explanation and personal opinion (Podgornik et al., 2017).

The integration of information literacy in biology lessons will have a positive impact on students' scientific literacy (Bruehl, Pan, & Ferrer-Vinent, 2015). Several studies have shown that the integration of information literacy in the curriculum in the form of a learning model has a positive effect on students' scientific literacy (Miller, 2017). Innovative learning which emphasizes active student activities that support information literacy will better high-level cognitive skills needed to solve problems and have the ability to distinguish between evidence-based scientific explanation and personal opinion (Podgornik et al., 2017).

Low information literacy can also be caused by schools not integrating information literacy into the curriculum (Saunders, 2012). Schools play an important role in training information literacy(Ministry of Education and Culture, 2017a). Information literacy needs to be integrated into learning effectively so that students can find, assess, and use the information to succeed in their schools, workplaces, and personal lives (Freeman & Lynd-Balta, 2010; Lupton, 2017; Phelps & Hyde, 2018). The integration of information literacy in biology lessons will have a positive impact on students' scientific literacy (Bruehl et al., 2015).

Educators play an important role in overcoming these problems so that students' information and scientific literacy can increase. Educators can integrate technology in learning, explain online search strategies to students, provide reliable sources that can be used as reference materials, and jointly evaluate the information obtained to be processed into knowledge (Coklar, et al. 2017). To integrate information literacy and scientific literacy is by using a problem-based learning model (Ministry of Education and Culture, 2017a).

CONCLUSIONS

The majority of scientific and information literacy are at the Developing level. Students have used science as a solution to problems in everyday life, but they understand phenomena and solutions simply. There is a positive relationship between scientific and information literacy of high school students. The higher the student's information literacy, the higher the student's scientific literacy. Based on the research that has been done, efforts are needed to increase scientific and information literacy for high school students, for example by applying innovative learning models.

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