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Scientific Literacy in Indonesian Secondary Education: Are We Ready to be Scientifically Literate Society?

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Abstract

The curriculum in Indonesia plays a pivotal role in equipping students with scientific literacy. It is important to undertake an exhaustive examination of curriculum documents to gauge how much scientific literacy is embedded within the curriculum and how effectively it fosters such literacy. Thus, this research aims to elucidate the presence of scientific literacy dimensions within the educational framework of Indonesia, thereby reflecting the government's commitment to nurturing scientifically literate societies. This study uses a qualitative approach to analyze Indonesian curriculum documents while employing data triangulation to ensure the research's validity and credibility. The findings indicate that the competencies outlined in the curriculum align with the dimensions of scientific literacy. This suggests that the Indonesian curriculum is designed to cultivate scientifically literate communities. However, further studies are required regarding implementing scientific literacy in the classroom.

Keywords: scientific literacy, science education, middle schools, science curricula, science teaching

INTRODUCTION

Literacy has been a fundamental pillar of the education sector for decades, and its significance has recently been underscored in Indonesia's curriculum and educational framework (Fitriani & Aziz, 2019). Literacy is viewed as the ability to read, write, and knowledge related to each other. Beyond reading, writing, and numeracy, literacy now encompasses a broader understanding of these skills and their practical applications in addressing societal challenges. This expanded concept, scientific literacy, emphasizes comprehending and utilizing information related to reading, writing, and numeracy to navigate and contribute to complex societal issues (Laugksch, 2000; Norris & Phillips, 2002; Sjöström & Eilks, 2018)

Within the domain of natural sciences, literacy emerges as a crucial facet. The comprehension and pedagogy of scientific concepts present formidable challenges, necessitating their integration into primary education frameworks. It is widely recognized that children inherently possess a heightened sense of curiosity (French, 2004), facilitating their receptivity to environmental stimuli. From infancy onward, children engage in exploratory activities, utilizing small-scale experiments to acquaint themselves with novel phenomena (French, 2004). Consequently, this developmental trajectory underscores the significance of early exposure to scientific inquiry, laying the groundwork for cultivating scientific literacy during the formative stages of education. Thus, socio-scientific issues as the representation of science and society interaction contribute to scientific literacy development (Colucci-Gray *et al.,* 2006).

Our surroundings serve as the foundation for understanding the importance of instilling scientific literacy. If children grasp scientific concepts early, the likelihood of misconceptions or difficulties in understanding and applying scientific concepts in daily life is minimized. Understanding natural science concepts extends beyond mere comprehension to include applying acquired knowledge. This is what is referred to as scientific literacy (Trefil, 2008). Preparing the next generation to be scientifically literate early is crucial for fostering a knowledgeable and technologically advanced society that contributes to national progress. Because scientific literacy is a process that encourages students to explore their surroundings and stimulates them to learn contextually, not just textually, children need encouragement to develop critical thinking by exposing them to socio-scientific issues (Kumar *et al.,* 2024) . Addressing this challenge, the Indonesian government has undertaken curriculum revitalization efforts to enhance the quality of education (Ministry of Education and Culture, 2022). Primary schools play a pivotal role in preparing the next generation to be literate, thus necessitating the cultivation of a culture of literacy from an early age (Listiani, 2022).

On the other hand, Vujičić *et al.* (2016) found that science is one of the most difficult fields to understand. This is evident from the low learning outcomes in physics, chemistry, and biology. Therefore, scientific literacy becomes a matter of great importance. According to the research, the level of scientific literacy is influenced by internal factors such as self-motivation and external factors such as learning approaches, family conditions, teaching approaches, and available opportunities (Jufrida *et al.,* 2019). In Indonesia, the level of students' scientific literacy is low (Jufrida *et al.,* 2019; Adnan *et al.,* 2021) which is also related to their learning achievements. In this context, literacy is related to how many books have been read and how well students understand the content of the books they have read.

Preparing a literate society, particularly scientific literacy (Trefil 2008). This is because the development of time and technology demands that society position itself and make the best decisions for itself and society. Directly or indirectly, the development of science will affect human life in terms of daily needs (Vujičić *et al.,* 2016). Therefore, the curriculum of Education in Indonesia, especially Science Education, has been designed to prepare students to face the developments of the 21st century, where a scientific knowledge foundation is required to navigate daily life (Pratiwi *et al.,* 2019). Based on the results of surveys conducted by PISA, the Indonesian government has made various efforts to improve the scientific literacy of students in Indonesia but still faces many challenges, as indicated by the low level of scientific literacy in Indonesia (Muhammad *et al.,* 2018; Narut & Supardi, 2019; Sutrisna, 2021). Narut & Supardi (2019) state that one way to familiarize students with scientific literacy is by designing a scientific learning environment. This inquiry-based learning will encourage students to develop scientific thinking, enabling them to think critically and conduct an in-depth analysis of every problem encountered to find the most appropriate solutions.

Considering the importance of scientific literacy, some countries such as Bolivia and Chile (Norambuena-Meléndez *et al.,* 2023) and Turkey (Cansiz & Cansiz, 2019) have integrated scientific literacy into the science curriculum. In China, the reformation of the science curriculum has made scientific literacy a consideration of core competencies for students' development (Yao & Guo, 2018). Through the Ministry of Education and Culture, Indonesia has made scientific literacy a special focus and an integral part of the curriculum. A previous study has shown that scientific literacy has become part of science teaching and learning in Independent Curriculum at the level of elementary school (Pertiwi *et al.,* 2023). However, the extent to which scientific literacy is reflected in the middle school science curriculum, the curriculum of Indonesian education still requires in-depth examination. Therefore, this article will discuss how Curriculum 2013 and Independent Curriculum reflect scientific literacy as part of the teaching and learning process.

METHOD

This qualitative study uses the document analysis method (Merriam & Tisdell, 2016; Flick, 2018; Morgan, 2022). The documents used as the data source for analysis are the Curriculum 2013 and the Independent Curriculum obtained from the website of The Ministry of Education, Culture, Research, and Technology. Triangulation is conducted to validate the data by collecting and analyzing data from other sources (Flick, 2018). In this study, we collected data from interviews. The sample for the interview was selected purposively, considering the willingness of the respondents to be interviewed (Creswell, 2014). Therefore, a science teacher at Junior High School and a Biology teacher at Senior High School were selected as the respondents to be interviewed due to their availability. The interview was conducted remotely using Zoom and lasted about 60-90 minutes (Seidman, 2006).

We analyze the curriculum documents and interview data based on their content (*Content Analysis*) through indexing and coding, which were then used to identify themes and patterns of information within the data (Yin, 2018). For the interview results, the data in the form of interview recordings were first transcribed into text for analysis. Once all the data were analyzed, developing a coding frame was next. The process flow of data analysis consists of initial coding, code grouping, trial coding, code evaluation, data analysis, and interpretation.

The coding frame was constructed by initially assigning codes drawn from the existing literature, particularly focusing on the dimensions of scientific literacy as delineated by PISA (OECD, 2016; Kiouri & Skoumiosis, 2017). During the data analysis phase, instances arose where information did not neatly align with the predetermined codes but remained relevant to scientific literacy dimensions. In such cases, the researcher introduced new codes (Creswell, 2014). Consequently, this study's approach to code development and data analysis involved a hybrid of both emergent and predetermined coding strategies.

After the coding process, the next step involves describing and categorizing themes for data analysis. This description offers an insight into the themes employed for data analysis. In this study, themes are structured around the dimensions of scientific literacy: knowledge, science process, and context (OECD, 2016; Kiouri & Skoumiosis, 2017). The final stage in data analysis is interpreting the results. When interpreting the data, researchers compare the obtained data with existing literature (Creswell, 2014), particularly literature related to curriculum and scientific literacy. Additionally, researchers also refer to the aims of this study in interpreting the research data.

RESULTS AND DISCUSSION

This research was conducted by analyzing the Curriculum 2013 documents and the Independent Curriculum, focusing on science subjects for the junior high school level and Physics, Chemistry, and Biology subjects for the senior high school level. In addition to analyzing curriculum documents, the researchers also interviewed two science teachers at Junior High School and two Biology teachers at Senior High School.

The curriculum analysis in this study is conducted by examining the competencies that students must achieve. In the Curriculum 2013, the core and basic competencies are analyzed to determine whether they reflect the aspects contained within the dimensions of scientific literacy. In the Independent Curriculum, we found that the elements and learning outcomes are essential components in providing an overview of the abilities that students must achieve. Table 1 presents the findings of this study, showing data analysis results from competencies in the Curriculum 2013 and Independent Curriculum.

Table 1. Components of scientific literacy in Indonesian secondary education science curriculums (Curriculum 2013 and Independent Curriculum)

Dimension	Aspect/Category	Description of the learning goals in both Curriculums
Knowledge	Content	The core competencies of science subjects at the middle and high levels state that students should be able to understand and apply knowledge (factual,

Dimension	Aspect/Category	Description of the learning goals in both Curriculums
		conceptual, and procedural) for the middle school level, while for the high school level, students are expected to understand, implement, analyze, and evaluate knowledge (factual, conceptual, and procedural).
	Procedural	Students are expected to understand the procedures or steps by which knowledge is acquired. However, the steps in the scientific investigation process have yet to be explicitly stated and are only presented as final conclusions, such as conducting simple experiments to understand concepts.
	Epistemic	This aspect still needs to be incorporated into the curriculum document.
Process skill	Describing, explaining, and predicting phenomena scientifically	In the Independent Curriculum, scientific process skills are the main elements that students must master by the end of the learning activities. This dimension of the scientific process consists of at least six inquiry skills that students must possess, namely:
	Evaluation and design	a. Observing b. Questioning and predicting c. Inquiring and conducting investigations d. Processing, analyzing data and information e. Evaluating and reflecting f. Communicating results
	Data interpretation	Science process skills are also part of core and basic competencies that the students should achieve in the Curriculum 2013. These process skills are not always a sequential set of steps, but rather a dynamic cycle that can be adjusted based on the development and abilities of the learners. This adaptability reassures educators and stakeholders about the effectiveness of the curriculum.
Contextual	Personal issues, local/global, current or ongoing, and related to science and technology.	At the Senior High School level or Phase F in the Independent Curriculum, students are expected to be able to examine personal, local, and global issues. These issues are the application of learning outcomes in Phases D and E, and students are expected to demonstrate their understanding of these issues. Meanwhile, in the Curriculum 2013, competency achievements related to context or context are in the Basic Competencies, where students learn each concept. For example, fluid dynamics is related to blood circulation in the body. Another example is vibrations and waves, which can be linked to the sonar system in animals.

Table 1 shows that competencies in the Indonesian science curriculum have incorporated the dimensions of science literacy, which consist of knowledge, process skill, and context. The dimension of knowledge consists of three aspects: content, procedural, and epistemic. Among these aspects, only the epistemic category needs to be incorporated into the competencies, while the other aspects are already present. Each curriculum emphasizes students' understanding of science concepts and processes in this first dimension of science literacy. The knowledge aspect of the dimension covers the facts, principles, or theories rather than applying them in contexts (Cansiz & Cansiz, 2019). For example, the description of the competencies related to the dimension of knowledge emphasizes the student's understanding of science concepts and procedures.

Furthermore, contextual and process skills are competencies in the Indonesian science curriculum. The process skill emphasizes the six inquiry skills that students should possess. Meanwhile, in terms of contextuality, high school students are gradually expected to examine and understand personal, local, and global issues. Within this dimension, learners are encouraged to develop critical thinking (Vieira & Tenreiro-Vieira, 2016) and are exposed to related socio-scientific decision-making problems (Yacoubian, 2018).

Scientific literacy has become a prominent educational goal and buzzword, though it is often considered an ill-defined and diffuse concept. Despite its vague nature, scientific literacy has persisted for decades and will likely remain central in science curriculum policy (Dillon, 2009). Within the development of science and technology in the era of 21st century, the demand for technical workers and a scientifically literate populace has been significant (Liu, 2009). Scientific literacy has emerged as a vital global imperative, aiming to equip the next generation with the readiness to tackle the challenges of daily life (Trefil, 2008). It is crucial to recognize that scientific literacy extends beyond grasping scientific concepts; it demands applying them effectively in everyday situations, particularly when making decisions. Such decisions must be grounded in scientific reasoning to ensure validity (Listiani, 2022).

What about scientific literacy in Indonesia? Has education in Indonesia prepared students to make decisions based on scientific thinking? According to the results, the curriculum in Indonesia already fairly reflects the Indonesian government's attention to preparing students in Indonesia to be scientifically literate. This is a response from the Indonesian government to the results of the PISA survey conducted every three years, which show that Indonesia is still ranked low (Narut & Supardi, 2019). The presence of the 2013 curriculum is one effort to improve students' scientific literacy, as in the 2013 curriculum, there have been refinements to the previous curriculum. In the 2013 curriculum, core and basic competencies have been formulated to meet the criteria of the scientific literacy model (Rahayu, 2014). However, the presence of scientific literacy in the curriculum is not adequate without the implementation in the classroom. Thus, teachers play an important role in promoting scientific literacy during the teaching and learning process (Altun-Yalçn *et al.,* 2011; Yao & Guo, 2018).

Indonesia is in the process of implementing a new curriculum called Independent Curriculum. Research data analysis indicates that Independent Curriculum reflects dimensions of scientific literacy, which can also be seen in the competencies that students must achieve. The contextual dimension is the scientific literacy dimension evident in Independent Curriculum (Suryaman, 2020). Independent Curriculum explicitly states that the content students learn refers to emerging issues on personal, local, and global scales. According to the standards set by PISA in 2018, individual, regional, and international issues or problems, both current and historical, are significant events that students need to understand using a foundation of scientific and technological understanding (OECD, 2019).

Regarding scientific literacy in the curriculum, both in Curriculum 2013 and the Independent Curriculum, science teachers state that the curriculum expects them to integrate scientific literacy into their teaching activities. In Curriculum 2013, teachers are expected to implement scientific learning to train participants to think scientifically. Referring to the framework established by PISA, scientific process skills are one aspect and dimension of scientific literacy (OECD, 2019). Respondents stated that to implement scientific literacy in teaching activities; students are directed to engage in interesting, interactive, and actively participatory learning activities by facilitating students to apply methods and processes in science such as observation, classification, data analysis and interpretation, communicating data, as well as understanding images, tables, and graphs (Utami *et al.,* 2016).

Meanwhile, scientific literacy in Independent Curriculum, according to one science teacher, allows science teachers to implement scientific literacy based on their understanding. One of the respondents mentioned that the Independent Curriculum provides flexibility for teachers to design the methods based on students' need "……Independent Curriculum empowers schools and teachers with greater autonomy in designing learning methods tailored to students' needs and local conditions." Teachers who understand scientific literacy believe that to encourage students to master scientific literacy, contextual learning should be conducted and oriented towards 21st-century learning, and subjects should be integrated to link scientific concepts with other lessons (Pratiwi *et al.,* 2019). This is because scientific literacy is not merely about understanding science concepts but also how to implement the knowledge to solve personal and social issues (Trefil, 2008; Norris & Phillips, 2002; Sjöström & Eilks, 2018). As we can see, there are more complex and controversial socio-environmental issues, such as Covid-19 pandemics (Valladares, 2021) that require multiple viewpoints

(Golluci-Gray *et al.,* 2006). Therefore, science teachers are encouraged to incorporate any related socio-environmental and sociocultural issues to promote scientific literacy.

The respondent's statement above indicates that the dimension of scientific literacy in the form of contextual learning has been reflected in the Independent Curriculum, where context-based learning is one part of the contextual dimension mentioned in the framework formulated by PISA for scientific literacy (OECD, 2019; Kiouri & Skoumiosis, 2017). China and Finland are two countries with high academic performance and achievement in international assessments such as the Programme for International Student Assessment that have translated and actualized scientific literacy in their National Primary Science Curricula (Wang *et al.,* 2019). This curriculum highlights science's role in transforming individuals and society, advocating for political action and engagement with socio-scientific issues. Contextual learning linked to everyday life can also facilitate student engagement in the learning process and develop 21st-century skills that can help students hone critical thinking skills. Regarding this, our first respondent believes that contextual learning and essential thinking skills contribute to students' scientific literacy development by stating, "…contextual learning, with teachers as facilitators, can provide science material according to students' environment and daily life, allowing students to be more engaged in the learning process." additionally, the second respondent states that Independent Curriculum promotes critical thinking, creativity, collaboration, and communication skills "…the Independent Curriculum encourages the development of critical thinking, creativity, collaboration, and communication skills, which are crucial in scientific literacy."

The development of science and technology requires people to be informed and educated with scientific and technological advancements to understand their implications and potential impacts on daily life, the environment, and society. Thus, science curriculum should help students assess scientific claims in the media that are relevant to their personal and public decision-making (Osborne & Allchin, 2024). Referring to the curriculum documents, Kurikulum2013 and Independent Curriculum, students in Indonesia have been prepared to become scientifically literate members of society. This is evident from the dimensions of scientific literacy reflected in both curricula implemented in Indonesia. These curricula are crafted to emphasize mastering scientific concepts and their practical application in daily life, addressing significant societal issues that require attention in education (Trefil, 2008; Suryaman, 2020). This shows that Indonesia has been striving to achieve scientific literacy for its citizens. The Ministry of Education's Curriculum 2013 and Independent Curriculum outlining key attitudes and process skills for Basic School pupils, such as curiosity, perseverance, and experiment design. The curriculum provides specific objectives and suggested activities to guide teachers in fostering reflective thinking, hands-on learning, and higher-order thinking skills.

CONCLUSION

Scientific literacy has become a crucial concern in education. Achieving a scientifically literate society requires attention, particularly from the government, to designing curricula that prepare students for scientific literacy. Indonesia is currently implementing Curriculum 2013 and is in the process of transitioning to Independent Curriculum. Upon reviewing both curricula, we found the dimensions and aspects of scientific literacy in the competencies set for students to achieve. The dimensions of scientific literacy reflected in the curriculum in Indonesia include knowledge, science process skills, and contextual understanding of science. Integrating the dimensions of scientific literacy into teaching activities plays a vital role in realizing scientific literacy. The contextual aspect of science learning activities can support students in better addressing everyday life issues, thereby contributing to the creation of a scientifically literate society. Although this study finds that most of the dimensions of scientific literacy are present in the curriculum, there are only a few recent studies on how well the Curriculum 2013 and Independent Curriculum align with the dimension of scientific literacy. Thus, further studies should be conducted regarding the relationship between curriculum documents and implementing scientific literacy in the classroom.

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