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Effectiveness of Differentiated Digital Student Worksheets Based on Socio-Scientific Issues to Improve Students' Science Literacy

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Abstract

The purpose of the study was to determine the effectiveness of differentiated digital student worksheets based on socioscientific issues to improve students' science literacy. The research employed a quasi-experimental design. The population was all students of class VII MTs N 1 Purbalingga in the 2023/2024 academic year. The sample was taken using the cluster random sampling technique and class VII A was selected as the experimental class and class VII D as the control class. The data collection instrument used a science literacy test. The data analysis technique in this research was carried out using quantitative description. The results of the research show that digital student worksheets are proven to be effective in increasing scientific literacy as seen from the average N-gain in the experimental class of 0,582 in the moderate category, higher than the control class of 0,323 in the moderate category. The results of the independent sample t-test are 0,001 < 0,05, which means there is a significant difference in increasing scientific literacy between the experimental and control classes. It can be concluded that SSI-based differentiated digital student worksheets are effective in increasing the scientific literacy of junior high school students.

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INTRODUCTION

Science learning in the 21st century aims to equip students with important competencies to face increasingly complex challenges in everyday life (Berg et al., 2021). In line with the learning paradigm that is moderate development to prepare students with knowledge and skills, such as mastery of technology, literacy, problem-solving, and leadership (Tohara et al., 2021). In this regard, science learning can be directed at training various 21st-century competencies, specifically scientific literacy, which is relevant to the nature of science learning (Hottecke & Allchin, 2020). These competencies refer to students' abilities in reading, writing, communicating scientific topics and issues, as well as understanding procedures for solving scientific problems in everyday life (Wahyu et al., 2020). Scientific literacy in the form of knowledge and understanding of scientific concepts and processes is needed by students in making decisions, and participating in diverse social and cultural life, as well as future career preferences (Widodo et al., 2020). Understanding scientific concepts and processes also helps students deal with everyday scientific situations, including understanding theories and terms in the field of science, as well as processes, methods, scientific investigations, and the goals of science (Kahler et al., 2020).

Considering the importance of literacy, students should have this competency to be ready to face the challenges of the 21st century. However, the facts show that the scientific literacy of Indonesian students is still low. The latest PISA results for 2022 saw a decrease in scores compared to the previous year, even though the ranking obtained increased. The low PISA results indicate that the science learning process has not provided opportunities for students to develop critically in solving problems in the field of science (Winarni et al., 2020).

Observation results of students senior high school in class VII MTs Negeri 1 Purbalingga also show that scientific literacy is still low. Preresearch preliminary data revealed that the average scientific literacy score was 42,23. This low level of scientific literacy is allegedly caused by several factors, such as science learning conditions, which are not yet fully student-centered and relevant to the context of everyday life. Science learning relies only on printed textbooks provided by the government, and the use of electronic media as a learning resource is not optimal. Apart from that, science learning is also dominant in textual knowledge, making it difficult to apply in everyday life. Students have low interest in reading due to learning resources that are dominantly written and not integrated with technology. This also explains the lack of optimal scientific literacy of students. Therefore, scientific literacy needs to be improved, namely through the provision of electronic learning resources that are contextual and relevant to students' learning needs.

One form of learning resource that can be used for science learning is digital student worksheets. Digital student worksheets are a form of presentation of electronic teaching materials that can be accessed via laptops, gadgets, and other media for certain learning units. Digital student worksheets can facilitate science learning that trains mastery of technology. This is in line with the 21st-century learning paradigm. The use of digital student worksheets equipped with animation, audio, and video makes learning effective and systematic (Hafsah et al., 2016). Apart from that, it can be a solution to overcome conventional learning, which causes students to be passive. In line with Haryanto et al. (2020), digital student worksheets help students be more active during learning, such as being able to solve material questions so that learning becomes more interactive. In connection with the aim of increasing scientific literacy, the development of digital student worksheets needs to contain content and learning processes that are contextual and relevant to students' needs.

A number of previous studies have reported learning approaches to be integrated into digital student worksheets that can increase scientific literacy, including digital student worksheets based on socio-scientific issues (SSI) in science learning (Hidayat & Hidayati, 2024; Khasanah & Setiawan, 2022; Rohmaya, 2022). The SSI approach is a development of the science, technology, and society (STS) approach and problem-based approaches. SSI refers to problems that include social issues that occur in society and are related to science. The uniqueness of these issues lies in their controversial nature because they present an issue that is viewed from multiple perspectives, it does not have a simple conclusion because it involves considerations of ethics and morality in the process of resolving these issues (Zeidler, 2015). The SSI approach is able to create more interesting learning content so that it can increase students' interest and motivation to learn (Sari et al., 2021).

Developing digital student worksheets using the SSI approach can facilitate contextual learning. Through SSI, students can practice analyzing problems from various perspectives. In line

with Nazilah et al. (2019), SSI can be a bridge between science content learned at school and concrete situations in everyday life. Thus, learning by implementing SSI can build scientific literacy (Calik & Wiyarsi, 2021). The use of learning topics adopted from everyday life problems allows students to be aware of the importance of science in understanding scientific phenomena and technological problems (Wiyarsi et al., 2021).

The integration of SSI in digital student worksheets can act as a learning context and provide a stimulus for students' cognitive development (Rohmaya et al., 2023). Learning activities with SSI will be more appropriate if combined with certain appropriate learning strategies so that their implementation can be more effective. One of the principles of learning in the independent curriculum is learning that is appropriate to the development and characteristics of students (Susilowati et al., 2022). Adapting learning to the development and characteristics of students can be achieved through differentiated learning strategies. This strategy can be applied in designing learning that accommodates students' strengths and learning needs with learning strategies and media (Herwina, 2021), including digital student worksheets.

In accordance with the results of observations of class VII students at MTs Negeri 1 Purbalingga, the characteristics of students in terms of interests and learning styles are quite diverse, so the differentiation strategy is appropriate to apply. Differentiated learning can provide opportunities for students to learn according to their needs efficiently (Fitriyah & Bisri, 2023). In differentiated learning, teachers create an inclusive environment and provide a variety of learning strategies, learning resources, and activities to meet the diversity of students. With this strategy, students can learn according to their level of ability, thereby increasing motivation and self-confidence in the learning process. Differentiated learning can create a pleasant learning atmosphere, train communication, collaborate learning, and select materials based on the diversity of characteristics and needs of students (Rahayu et al., 2023).

In science learning, the development of differentiated digital student worksheets can be carried out to support the implementation of the independent curriculum and has proven effective in improving science learning outcomes (Fitra, 2022; Hardiansyah et al., 2023). The existence of differentiated strategies can stimulate students to develop their capacity as lifelong learners and help them achieve learning success (Tilamsari et al., 2023). Apart from that, a number of previous studies also reported effectiveness in increasing scientific literacy (Ermawati et al., 2023; Wijayanti et al., 2024). The differentiated strategy is also closely related to the global sustainable education agenda, which emphasizes scientific literacy related to socio-scientific issues (Mahdiannur et al., 2022).

Based on the background description that has been presented, the implementation of digital student worksheets that integrate SSI and differentiated strategies needs to be done. Previous studies have revealed the potential of SSI and differentiated strategies to improve science literacy, but these studies have not been carried out in an integrated manner. The purpose of the study was to determine the effectiveness of differentiated digital student worksheets based on socioscientific issues to improve students' science literacy.

METHOD

This research was carried out based on the quasi-experimental nonequivalent control group design. The pretest was conducted to determine students' scientific literacy. After conducting the pretest, the experimental class was given treatment by implementing SSI-based differentiated digital student worksheets. While the control class was given learning using conventional student worksheets. After the learning process, a posttest was conducted on both classes. The population was all students of class VII MTs N 1 Purbalingga in the 2023/2024 academic year. The sample was taken using the cluster random sampling technique and class VII A was selected as the experimental class and class VII D as the control class.

The data collection instrument used a science literacy test. This instrument contains 19 questions consisting of multiple-choice, complex multiple-choice, essay, true-false, and matching questions. These questions are arranged based on science literacy indicators, namely 1) explaining phenomena scientifically, 2) evaluating and designing scientific investigations, and 3) interpreting information and evidence scientifically (OECD, 2019). The previously developed test instrument was validated by experts to determine the validity of the test and was first tested to determine the consistency of the questions and the reliability of the instrument. Thus, a valid and reliable science literacy test instrument was obtained.

The data analysis technique in this research was carried out using quantitative description.

The effectiveness of digital student worksheets is demonstrated by the N-gain and independent sample t-test. The calculation of N-gain from pretest and posttest scores uses the following formula (Muntari et al., 2024)

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle}$$

Information

$\langle g \rangle$: average normalized gain
$\langle S_{post} \rangle$: score after treatment
$\langle S_{pre} \rangle$: score before treatment

The N-gain value obtained is then converted into N-gain gain criteria, and the size of the (g) factor is categorized as in Table 1.

Table 1. N-Gain Value Criteria

N-gain Value	Criteria
$0.70 \leq (g) \leq 1.00$	High
$0.30 \leq (g) < 0.70$	Moderate
$(g) < 0.30$	Low

Digital student worksheets are said to be effective if they are in the medium or high category (Dalaila, 2022). To support the analysis results from the N-gain score test, an independent sample t-test was carried out to analyze whether there was a significant difference in the increase in scientific literacy between the control and experimental classes. Before carrying out the independent sample t-test, the normality and homogeneity test requirements were checked.

RESULT AND DISCUSSION

The effectiveness of SSI-based differentiated digital student worksheets in increasing scientific literacy refers to the N-gain and independent sample t-test results. The results of the average score and N-gain are seen in Table 2.

Table 2. Mean Score and N-gain for Science Literacy

Class	Average Score		N-gain	
	Pre	Post	Average	Criteria
Experiment	51.95	79.88	0.582	Moderate
Control	49.16	65.32	0.316	Moderate

Based on Table 2, the SSI-based differentiated digital student worksheets used in the experimental class are more effective in increasing students' scientific literacy compared to the teaching materials used in the control class. Although both classes experienced an increase in scientific literacy with a "moderate" N-gain category, the experimental class showed a higher increase in the average posttest score and N-gain value.

Next, an independent samples t-test was carried out on the N-gain values of the experimental and control classes to analyze whether there was a significant difference in the increase in scientific literacy between the control and experimental classes. Before the independent sample t-test is carried out, the blood has fulfilled the prerequisite tests for analysis in the form of normality and homogeneity tests. The results of the independent sample t-test can be seen in Table 3.

Table 3. Independent sample t-Test Results for Scientific Literacy

	T	Df	Sig. (2-tailed)	Information
N-gain	8.053	68	< 0.001	There are significant differences

Based on Table 3, it is known that the independent sample t-test results obtained a Sig value. < 0,001, these results indicate that the Sig. less than 0,05, which means that there is a significant difference in increasing scientific literacy between the experimental and control classes. Improving students' scientific literacy can also be reviewed from each indicator, the results of which can be seen in Figure 1.

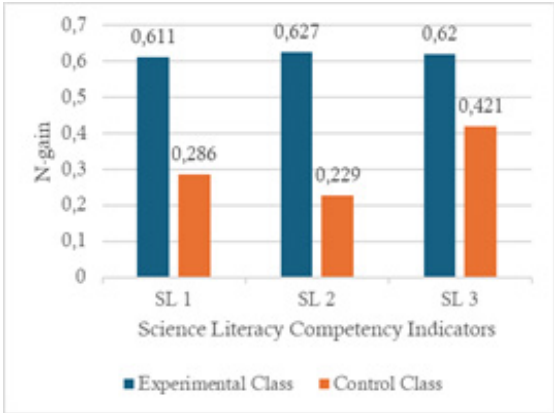

Figure 1. Improvement of Each Science

Literacy Competency Indicator
SL 1:Explain phenomena scientifically
SL2:Evaluate and design scientific investigations
SL 3:Interpret information and evidence scientifically

Based on Figure 1, it shows that the experimental class obtained a higher increase in all indicators of science literacy competency compa-

red to the control class. In the SL1 indicator, the experimental class recorded an increase of 0,611 with moderate criteria, while the control class was only 0,286 with low criteria. The SL2 indicator in the experimental class showed an increase of 0,627 with moderate criteria, much higher than the control class which was only 0,229 with low criteria. In the SL3 indicator, the experimental class was also higher with an increase of 0,620 compared to the control class which was 0,421 even though both were included in the moderate criteria. These data indicate that SSI-based differentiated digital student worksheets can be said to be more effective in improving students' science literacy compared to conventional teaching materials used in the control class.

Overall, the research results show that the experimental class that used SSI-based differentiated digital student worksheets had better effectiveness in increasing scientific literacy than the control class. The use of SSI-based differentiated digital student worksheets provides real context that is relevant to student's daily lives, thereby creating meaningful, interesting learning and encouraging students' learning engagement (Sadler & Zeidler, 2019). Furthermore, digital student worksheets equipped with a variety of dynamic content can facilitate students to interact directly with learning material and learn according to their needs, interests, and preferences.

The SSI content in digital student worksheets presents social issues that occur in society and are related to science. The SSI content can help students link scientific concepts with relevant social issues, there by encouraging learning activities that require critical and reflective thinking. Integration between social issues and scientific concepts helps students see the real application of the concepts learned in science. Therefore, the use of digital student worksheets in the SSI context directly facilitates students to have skills in scientific literacy. This is supported by previous research, which reveals that teaching materials with an SSI context can increase scientific literacy (Anggraini et al., 2020; Dewi et al., 2022; Hidayat & Hidayati, 2024; Khasanah & Setiawan, 2022;). Apart from that, SSI also increases curiosity, gives students consideration in determining solutions, and trains students in evaluating scientific data and information (Rizal et al., 2019; Rostikawati & Permanasari, 2016; Zeidler et al., 2019).

Meanwhile, the differentiation strategy in the digital student worksheets developed applies differentiation of content, processes, and products, which are packaged interactively with the use of technology. The differentiated strategy provides various forms of presentation and use of learning materials so that students are not only focused on one form so that students can choose and know more SSI issues that are relevant to the scientific concepts being studied. The application of this differentiated strategy ensures that each student can achieve their maximum potential in scientific literacy. This finding is in line with research results which state that differentiation strategies can improve learning outcomes and provide opportunities for students to be able to learn efficiently (Haelermans, 2022; Iskandar, 2021; Kamal, 2021; Suwartiningsih, 2021).

The effectiveness of differentiated and SSI-based digital student worksheets in increasing scientific literacy can be seen from the stages of presenting the material on digital student worksheets. Learning activities begin with problem analysis, namely, students are given SSI problems which are presented in the form of reading, pictures, or videos. Problem analysis activities involve students thinking critically about solving problems, which is an essential component of scientific literacy. This stage is the starting point for students to see the relevance of the material they will study to the real world. In line with Suhirman & Khotimah (2020), in the process of analysing problems, students need to apply scientific concepts to strengthen their understanding of these concepts. Furthermore, analysing problems can encourage students to search for and evaluate relevant information to create solutions (Shultz & Li, 2016).

The next learning activities are clarification of the science and refocus on socio-scientific dilemmas which facilitate students to master SSI issues from a scientific perspective and refocus attention on related issues. By studying SSI issues and clarifying the science behind these issues, students are trained to apply scientific knowledge in real ways. Understanding the science behind socio-scientific issues will facilitate the development of social awareness through how science can be used to make responsible decisions in everyday life. In line with Husniyyah et al. (2023), the integration of SSI in science learning increases understanding of complex social issues and helps in making informative decisions. Thus, this scientific clarification activity is relevant to the first indicator of scientific literacy, namely explaining phenomena scientifically.

Learning activities in digital student worksheets that can also increase scientific literacy are the role play stage, where students are directed to discussions, performances, presentations, and

work with product differentiation. This digital student worksheet facilitates students to explore various scientific and social perspectives, internalise scientific concepts, and develop critical argumentation and decision-making skills through the role-play stage. In this way, students can carry out tiered activities in learning scientific concepts and utilize more knowledge according to students' learning abilities. In line with Maniatakou et al. (2020) role play activities on science issues expose students to situations that require exploration of scientific concepts, although at varying levels. Furthermore, the differentiation strategy facilitated in this digital student worksheet can help students achieve optimal learning outcomes, including product differentiation (Herwina, 2021).

A series of learning activities in digital student worksheets ends with a meta-reflection activity developed to facilitate students analysing and evaluating the learning process with differentiated and SSI-based strategies.This reflection will encourage students to be more aware of learning strategies, the content of the material being studied, and ways to improve understanding. Thus, meta-reflection helps increase scientific literacy, namely motivating students to face challenging science tasks with perseverance (Michalsky, 2021). Differentiated and SSI-based digital student worksheets are a learning strategy that encourages student activity rooted in a constructivist approach. The use of digital student worksheets not only makes students passive in receiving information, but also actively interacts with the media, available SSI issues, and the scientific concepts being studied. Therefore, digital student worksheets are more effective in increasing scientific literacy than using conventional teaching materials (control class).

Effective improvement of science literacy also occurs in the science literacy competency indicator. Differentiated digital student worksheets based on SSI provide real contexts that are relevant to everyday life, thus facilitating a deep understanding of the relationship between scientific concepts and phenomena in society that occur. In digital student worksheets, problem analysis activities and focus on SSI dilemmas are relevant to improving science literacy competencies in explaining phenomena scientifically. For example, in digital student worksheet b the influence of the environment on living things, students are invited to analyze scientific phenomena related to biotic and abiotic factors that affect living things. The support of content differentiation facilitates more ways for students to be involved in explaining phenomena scientifically. In line with Zulkhi et al. (2014) different and relevant discourses with students' interests effectively increase student participation.

Differentiated digital student worksheets based on SSI have proven to be effective in the scientific literacy competency indicator of evaluating and designing scientific investigations than conventional teaching materials. SSI content involves hands-on student activities, while differentiation supports the adjustment of learning tasks according to student abilities and needs. The activity of designing investigations arises especially when students clarify scientific concepts, such as in the case of wastewater in aquatic ecosystems, students are invited to design simple experiments. Meanwhile, meta-reflection activities encourage students to analyze and evaluate the learning process and outcomes obtained, including scientific understanding. Thus, digital student worksheets can improve student competence in evaluating and designing scientific investigations that are not facilitated in conventional teaching materials. In line with Rizal et al. (2019) that SSI learning is able to provide considerations for students to make decisions in determining solutions.

Differentiated digital student worksheets based on SSI also involve student activities in analyzing information obtained in role play activities. After obtaining information from various sources, students are invited to interpret, identify patterns, and make logical conclusions from the available evidence. Differentiation in digital student worksheets facilitates tiered activities, so that students can develop skills in analyzing gradually. Furthermore, the presence of activities in presenting work also deepens the activity of interpreting information because it includes the activity of changing data from one representation to another, such as from text information to images or diagrams. In line with Zeidler et al. (2019) that SSI integration is important to teach in order to train students in evaluating scientific data and information.

Both overall and scientific literacy competency indicators show that SSI-based differentiated digital student worksheets are more effective than conventional teaching materials. Conventional teaching materials tend to focus on memorizing scientific concepts without real application contexts, thus reducing students' learning opportunities to relate science to everyday phenomena. Furthermore, conventional teaching materials also do not provide opportunities to design scientific investigations independently, but rather follow predetermined steps. Therefore, the use of SSI-based differentiated digital student work-

sheets provides more effective improvements because it facilitates students' learning processes in explaining scientific phenomena, designing and evaluating scientific investigations, and interpreting information and evidence scientifically.

CONCLUSION

Based on the results of the study, it can be concluded that digital student worksheets differentiated based on socioscientific issues have proven effective in improving scientific literacy with an average N-gain of the experimental class of 0,582 in the moderate category, higher than the control class of 0,323 in the moderate category. In addition, it is supported by the results of the independent t-sample test which obtained a Sig. <0,001 value, indicating that there is a significant difference in increasing scientific literacy between the experimental class and the control class.

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