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The Performance Of NGSS-Based Teaching Materials Integrated Game Discovery (BANDI) On Senior High School Students Scientific Literacy Skills

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Abstract: Scientific literacy is an essential skill to meet 21st-century challenges, necessitating its facilitation in educational settings. At the senior high school level, scientific literacy can be enhanced through NGSS-based teaching materials integrated with game discovery (BANDI). This study aims to analyze BANDI's performance in facilitating students' scientific literacy improvement. The research adopts a quasi-experimental design with a Nonequivalent Pretest-Posttest Control Group. The sample comprises 50 class X IPA students from SMA 01 Labuhan Haji, selected through cluster random sampling. BANDI's performance is evaluated based on its practicality and effectiveness. Practicality data were collected through observations and questionnaires, while effectiveness was assessed using a scientific literacy test adapted from PISA. Practicality data were analyzed descriptively, while effectiveness data were analyzed using statistical tests, including homogeneity, normality, Mann-Whitney, and Independent T-test. Results indicate that BANDI's practicality was validated through high implementation ratings and positive responses from students and teachers (75%-96.88%, 81.86%, and 88.39%). Effectiveness was confirmed via N-Gain analysis, showing a moderate improvement in the experimental class (0.51). Hypothesis testing further demonstrated significant differences in scientific literacy outcomes between the experimental and control classes ($p < 0.00$), with the experimental class achieving a higher average score (63.87) than the control class (38.70). Therefore, BANDI is effective in improving scientific literacy in terms of both practicality and effectiveness.

Keywords: BANDI, Performance, and Science Literacy

Introduction

Scientific literacy is one of the crucial skills students must possess in 21st-century learning (Monica, 2021; Yuliati, 2017). In the 21st century, many students are faced with crucial choices related to their lives, especially in the fields of social, pharmaceutical, energy, and environmental issues (Wield et al., 2013). So the role of scientific literacy is very important because it can provide better capacity and make smarter and more informed decisions that will positively affect the quality of life for them (Zen, 1990). Scientific literacy is becoming one of the trends to be used as a learning orientation. Even the Organization for Economic Co-operation and Development (OECD) has conducted an assessment of scientific literacy in many developed and developing countries, one of which is Indonesia (Schleicher, 2019).

The results of the assessment on the Program for International Student Assessment (PISA) by the OECD show that the scientific literacy of students in Indonesia is still relatively low. PISA data shows that Indonesia has never been out of the top ten of the lowest ranking evaluation results (Schleicher, 2019). Indonesia is ranked 74th out of 79 participating countries with a score of 396 in the last PISA assessment. Indonesia's score is relatively low because it is far from the average PISA participant score of 489 (Schleicher, 2019).

Less supportive learning activities are seen as the cause of students' low scientific literacy learning outcomes (Angraini, 2014; Yuliati, 2017). Kusdiningsih stated that it is clear that so far the learning applied has not been optimal in equipping science problem-solving

skills (problem literacy) (Kusdiningsih et al., 2016). Mcneill stated that student learning activities in learning still rarely facilitate activities to explain scientific phenomena and evidence, and there are rarely activities to obtain data and interpret data to answer a problem (McNeill, 2011). Dewi et al. stated that learning activities so far tend to focus on remembering and understanding activities that are not yet adequate to support scientific literacy-oriented learning (Dewi et al., 2019).

Next Generation Science Standard (NGSS)-based teaching materials are seen as one of the solutions to overcome the problem of learning activities that are still less supportive to improve scientific literacy. NGSS is a learning standard that develops a three-dimensional approach to improve the quality of science learning. The three dimensions consist of STEM (Science, Technology, Engineering, Math), Disciplinary core idea (DCI), and Crosscutting Concept (CC) (Cisterna et al., 2020; Skrimponis & Makris, 2020). The three dimensions are considered compatible to train scientific literacy. DCI is an approach that contains the core content of science material in learning that can be used to present scientific content and scientific phenomena (Duncan et al., 2018). STEM is related to activities that are thick with the nuances of scientific literacy with an emphasis on technical activities, technology, and the use of mathematical concepts (Skrimponis & Makris, 2020). Crosscutting Concepts can facilitate ways of explaining, interpreting, and evaluating phenomena scientifically in subject matter (Cisterna et al., 2020; Osborne et al., 2018).

Aspects that need to be considered in the application of teaching materials are the use of appropriate learning models. The learning model is the main point so that the teaching materials applied are by the goals and competencies to be achieved (Panggabean & Danis, 2020). Based on the approach to the NGSS, the discovery learning model is suitable for use in the NGSS-based learning process (Sani et al., 2018). Discovery learning syntax can accommodate the integration of DCI on stimulation, STEM on data collection and processing, and Crosscutting concepts on generalization (Astuti, 2015; Gershman et al., 2015).

Learning with NGSS-based teaching materials with the discovery model is still rarely used in learning, so it requires a component to attract students' attention to using NGSS in learning. For this reason, the integration of games in the discovery learning step needs to be done to increase students' attention and motivation in learning (Ariana et al., 2020; McDevitt, 2013; Ratminingsih et al., 2018). Good attention and motivation can increase the achievement of learning objectives (Dwija, 2008; Mawarsih & Hamidi, 2013). In addition, the use of learning materials as the basis for game design themes can improve mastery of material content (Roungas & Dalpiaz, 2015) which will have an impact on increasing scientific literacy.

The use of teaching materials to support scientific literacy has been carried out in several studies (Andaresta & Rachmadiarti, 2021; Komalasari et al., 2019). Sari et al. using inquiry-based teaching materials to improve scientific literacy (Komalasari et al., 2019), then Andranesta & rachmaiarti use STEM-based E-books to improve scientific literacy (Andaresta & Rachmadiarti, 2021). Based on research by Sari et al. and Andranesta & rachmaiarti teaching materials still focus on aspects of the model, method, and the digitization of learning materials. Learning requires other important aspects to support scientific literacy such as learning activities using mathematical models with the help of technology and the integration of games to increase students' attention and motivation (Cisterna et al., 2020; Ismail, 2016; Kabunggul et al., 2020).

NGSS-based teaching materials integrated with games in discovery learning (BANDI) have great potential in facilitating scientific literacy learning. The potential of NGSS-based teaching materials integrated with game discovery can accommodate the use of mathematical models, the use of technology, and the integration of games into learning. Based on the potential of BANDI, research entitled "The Performance of NGSS-Based Biology Teaching Materials Integrated Game Discovery (BANDI) To Improve Students' Science Literacy" becomes necessary to carry out. The teaching materials from this research are expected to contribute to increasing the scientific literacy of high school students in schools.

Method

This is quasi-experimental research that aimed to analyze the performance of BANDI materials in improving the scientific literacy of

high school students. The Nonequivalent Pretest-Posttest Control Group Design was used in this study (Audrey et al., 2019) as shown in **Table 1.**

The population in this study were all students of class X MIPA SMAN 01 Labuhan Haji. The sampling technique used was the cluster random sampling technique. The selection of the sampling technique was based on the test design at the implementation stage which used a quasi-experimental and it was not possible to change the class group participants that had been determined by the school. The sample consisted of two classes with 50 students consisting of 16 males and 34 females. The number of meetings in this study was six times, where the first meeting was for socialization, the next four meetings were for treatment, pre-test, and post-test for each meeting, and the last meeting was for gathering practicality questionnaire data. The learning process is carried out four times over two weeks (two meetings each week).

Table 1. The research design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_2
Control	O_3	X_2	O_4

Annotation: O_1 = scientific literacy pretest on experiment group; O_2 = scientific literacy posttest on experiment group; O_3 = scientific literacy pretest on control group; O_4 = scientific literacy posttest on Control group; X_1 = Experiment group treatment (Learning with BANDI); X_2 = Control group treatment (Learning with conventional media).

The treatment in this study referred to (X_1) learning with BANDI teaching materials to enhance scientific literacy on ecosystem topics and (X_2) learning with conventional media that are already used by the teacher materials on ecosystem topics. Before being implemented as a treatment in this study, the BANDI teaching materials were examined for validity, reliability, and readability. The data for validity and reliability was gathered using questionnaire sheets based on Likert scales consisting of five scoring scales for each item declaration (Bahtiar & Prayogi, 2012). The validity was calculated with the content validity ratio and content validity index (CVR-CVI) (Lawshe, 1975). Then the reliability was calculated with the equation of percentage of agreement (Borich, 1994). The results of the validity and reliability test by experts show that the BANDI is valid and reliable to be implemented with a CVI value of 0,96 and PA 89,80%. As for readability data using text on BANDI teaching materials consisting of at least 100-200 words. The text used in the readability test was taken systematically. Taking 2 samples for each topic with 4 main topics in total. The readability was calculated with Flesch-Kincaid *Grade Level* (FKGL) (Wekes et al., 2022). The results of the readability analysis obtained an FKGL score of 10.96 which indicates that BANDI is suitable for users of grade 10 senior high school, which in this study is the subject of the research.

BANDI's performance when implemented is reviewed based on aspects of practicality and effectiveness in supporting scientific literacy learning. Practicality data consists of data on the the level of learning implementation and data on student and teacher responses about the practicality of BANDI in learning. The data on the implementation of learning was obtained through the observations of three observers using observation sheets based on Likert scales consisting of five scoring scales for each item declaration. Then the student and teacher response practicality data were obtained through a practicality questionnaire based on Likert scales consisting of five scoring scales for each item declaration The practicality data was calculated using the percentage of response values (Shellawati & Sunarti, 2018). Then the category of practicality level can be seen in **Table 2**.

Table 2. Practicality assessment category

Response values (%)	Criteria
76-100%	Very high
51-75%	High
26-50%	Moderate
0-25%	Low

(Source: adapted from Arikunto, 2010)

Data on the effectiveness of BANDI was obtained through a scientific literacy test instrument in the form of multiple choice adjusted to indicators of scientific literacy. Indicators of scientific literacy in this study refer to the indicators used by the Program for International Student Assessment (PISA), namely, Explaining phenomena scientifically, Evaluating and designing scientific inquiry, and Interpreting data and evidence scientifically.

Before being implemented, the test instrument was examined for validity and reliability theoretically and empirically. The theoretical data was gathered using

questionnaire sheets based on Likert scales consisting of five scoring scales for each item declaration (Bahtiar & Prayogi, 2012). The theoretical aspect of validity was calculated with the content validity ratio and content validity index (CVR-CVI) (Lawshe, 1975). Then the theoretical aspect reliability was calculated with the equation of percentage of agreement (Borich, 1994). The theoretical aspect results of the validity and reliability test by experts show that the BANDI is valid and reliable to be implemented with a CVI value of 0,95 and PA 90,00%. The empirical data is obtained through the responses of students who have studied ecosystem material.

The empirical aspect of validity was calculated with the Relation Product moment (RPM) (Arikunto, 2019). Then the empirical aspect reliability was calculated with the equation of Cronbach alpha (CR) (L. R. Setiawan et al., 2020). The empirical results of the validity and reliability test by student response show that the test instrument is valid and reliable to be implemented with RPM sig. p-values <0,05 and CR value 0,677. Based on the analysis that has been done, the test instrument is confirmed theoretically and empirically feasible to be used in research. The scientific literacy criteria based on the scores obtained through the test instrument were adapted from Faiqoh (Faiqoh et al., 2018), which are presented in Table 3 as below.

Table 3. Category of scientific literacy achievement

Score	Criteria
80-100	Very high
66-79	High
56-65	Moderate
40-55	Low
0-39	Very Low

The scores obtained by students in this study were analyzed using the N-gain test and inferential statistical tests to describe the effectiveness of BANDI. N-gain test serves to assess the improvement of student learning outcomes. Then statistical analysis serves to assess the level of significance of the BANDI effect on learning outcomes through hypothesis testing. Increasing the score of scientific literacy learning outcome was analyzed using the N-gain equation according to Hake's theory (1999) (Sundayana, 2014) with the criteria as in Table 4.

Table 4. N-Gain criteria index

N-Gain Score (g)	Criteria
g = 0,0	Stable
0,0 < g < 0,30	Low
0,30 < g < 0.70	Moderate
0.70 < g < 1.00	High

Inferential statistics used to determine the significance level of differences in learning outcomes between the two sample groups of students are the Independent T-Test (T-test) and Mann-Whitney using SPSS 21 software. The Independent T-Test use for data that meet normality and homogeneity prerequisite. The normality test to determine the distribution of the data used the Shapiro-Wilk with a significance level of 0.05, while the homogeneity test was used to see whether or not the variation in the distribution was the same using one way ANOVA with a significance level of 0.05. Then the data that does not meet the criteria in the prerequisite test used an alternative non-parametric test, namely the Mann-Whitney test.

Result and Discussion

The performance of BANDI was reviewed through the practicality and effectiveness aspects. Aspects of the practicality of BANDI are described through the implementation of learning data and the practical response of teachers' and students' data. Furthermore, the Effectiveness of BANDI is described through data on student acquisition scores, N-Gain analysis, and hypothesis testing of differences through inferential statistics. The details are presented in the following description:

BANDI Practical Performance

The practical aspects of BANDI in learning scientific literacy can be reviewed theoretically and empirically (Gazali, 2016). The empirical review is described through the implementation of learning data (Table 4). The theoretical review is described through student and teacher response data (Table 5). The practicality response data is then used to determine the practicality criteria for teaching materials (Gazali, 2016).

The level of learning implementation is assessed by the observer through observation in the learning process. Assessment by observers is intended to determine the level of practicality of teaching materials from an empirical perspective. Practicality from an empirical point

of view is the level of implementation of learning using BANDI. Data were obtained through the use of a learning implementation questionnaire. The questionnaire instrument broadly measures the implementation of BANDI in the preliminary stage, core stage, and closing stage activities.

Preliminary stage activities are generally in the very high category (Table 4). Two indicators obtained a perfect implementation score, namely the aspect of delivering features and students' attention. Core stage activities get a lower level of implementation than the preliminary activities. In general, the core activities obtained the implementation of learning in the high category. All indicators received a rating of 75% (Table 4). Closing stage activities are in the category of very high overall. Three of the four indicators get a perfect score. The lowest score in the closing stage activity was even at 87.50% (Table 4). Based on the data obtained, it can be said that BANDI has high to very high performance in facilitating scientific literacy learning. Observer assessment is important to obtain as a reference for the level of friendliness/ease of use of the BANDI directly through real observations in the implementation of learning (Gazali, 2016).

Table 5. Data on the level of learning implementation

Indicator	Score	Criteria
Preliminary stage activities		
BANDI teaching materials based on android attract students' attention	100,00%	Very high
BANDI can be used to convey learning objectives easily	87,50%	Very high
The teacher introduces the features that exist in the BANDI well	100,00%	Very high
Students can recognize the features that exist in BANDI well	87,50%	Very high
Average	93,75%	Very high
Core stage activities		
The material in BANDI can be used as a learning stimulus	75,00%	High
Games on BANDI can attract students' attention well	75,00%	High
Students carry out activities to explain phenomena scientifically through BANDI	75,50%	High
Students carry out activities to evaluate and design scientific investigations through BANDI	75,00%	High
Students carry out data interpretation activities and scientific evidence through BANDI	75,00%	High
Students express opinions using crosscutting concepts through BANDI	75,00%	High
Average	75,00%	High
Closing stage activities		
Asking students to reflect on learning activities	87,50%	Very high
Allow students to ask questions	100,00%	Very high
Inform the next teaching material	100,00%	Very high
Closing the learning activities with prayers and greetings	100,00%	Very high
Average	96,88%	Very high

Practical responses of teachers and students are intended to determine the level of practicality of teaching materials from a theoretical point of view. Practicality from a theoretical point of view is the response of students and teachers about the practicality of using BANDI in learning after it has been implemented. Data were obtained through the use of a practicality questionnaire. The questionnaire instrument broadly measures the level of practicality which is characterized by attractiveness, enjoyment of use, motivation, activity, and ease. Student and teacher response data shows that the BANDI application is included in the very high category. This practical level can be seen through the acquisition of response scores which are all above 75%. Even the teacher thought that the illustration on the BANDI could increase the understanding of the material by 100% (Table 5). A similar thing was reported by (Gazali, 2016) who developed mathematics teaching materials with a very practical category. Student and teacher responses are important to obtain as a basis for considering the level of user-friendliness of the product from the user's perspective.

BANDI effectiveness performance

Effectiveness performance needs to be tested to analyze how big and significant the increase in learning outcomes is through the

treatment given (R. H. Setiawan & Harta, 2014). The effectiveness test in this study assessed the level of improvement and significance of scientific literacy through the use of BANDI. Effectiveness tests are important to do to produce good teaching materials (Wuryanti & Kartowagiran, 2016). The effectiveness test can be described through the average difference through N-gain and inferential statistical tests (R. H. Setiawan & Harta, 2014; Sundayana, 2014)

The overall average score of the pretest for scientific literacy in the experimental class is in the very low category, the same trend occurs in the control class (Table 6). Wulandari and Salihin stated that the range of values 0-39 was in the very low category (Wulandari, 2016). Then the overall average score of the posttest shows that the experimental class is in the moderate category and the control class is still in the very low category (Table 6).

The assessment of scientific literacy in the pretest and posttest showed an increase from the pretest to the posttest in both the experimental and control classes (Table 6). However, the average of the experimental class was higher than the control class on all posttests of each meeting. Afriana et al., Niswatuzzahro et al., as well as Albab and Wijiastuti (2018) found something similar where the use of STEM approaches, discovery models, and games made the class that was given treatment have an increase in the average score (Afriana et al., 2016; Albab & Wijiastuti, 2018; Niswatuzzahro et al., 2018). These findings show that aspects of STEM, model discovery, and games in product development indicate a role in increasing scientific literacy.

The results of the N-gain analysis show that the experimental class tends to increase while the control class tends to decrease (Table 6). The majority of the N-gain analysis in the experiment was in the medium category while the majority in the control class was in a low category. The difference in the N-gain score shows that BANDI can increase the effectiveness of science literacy learning in schools.

Scientific literacy can be increased through the use of BANDI which is influenced by the NGSS component, namely discovery models, the use of learning games, and digital teaching materials. Afriana et al. stated that NGSS with a STEM approach can help understand teaching materials in depth and form an active attitude in learning (Afriana et al., 2016). In addition, the components of problem identification and formulation of hypotheses at BANDI greatly provide opportunities for the formation of critical and analytical thinking attitudes for students in learning so that they can help improve students' scientific literacy competence (Niswatuzzahro et al., 2018). Furthermore, students' scientific literacy can be optimized through the use of scientific steps of discovery model activities which are manifested in LKPD on BANDI materials (Niswatuzzahro et al., 2018). LKPD at BANDI also designs continuity and proof between scientific theory and facts that can improve scientific literacy (Niswatuzzahro et al., 2018).

Table 5. Data on the practical response of teachers and students

Indicator	Response			
	students	**Criteria**	**teachers**	**Criteria**
BANDI design attractiveness	76,00%	H	75,00%	H
The appeal of the cover describes the content	82,00%	VH	100,00%	VH
The pleasure of using BANDI	89,00%	VH	75,00%	H
Increased motivation to learn using BANDI	81,00%	VH	87,50%	VH
Comprehensive presentation of material on BANDI	79,00%	H	87,50%	VH
Increased depth of understanding of the material	87,00%	VH	87,50%	VH
Increased learning activity	79,00%	H	87,50%	VH
Ease of reading text	86,00%	VH	100,00%	VH
The attractiveness of the display of teaching materials	81,00%	VH	75,00%	H
Improved ease of understanding the material	91,00%	VH	87,50%	VH
Easy to understand image display	80,00%	VH	100,00%	VH
Improved understanding of the material with the help of pictures and illustrations	77,00%	H	100,00%	VH
Ease of use of sentences	79,00%	H	87,50%	VH
Communicative use of language	79,00%	H	87,50%	VH
Average	81,86%	VH	88,39 %	VH
SD	0,046		0,091	

Annotation: VH (very high), H (High), SD (standard deviation)

BANDI which is applied through the discovery learning model can improve scientific literacy. Niswatuzzahro et al. stated that the combination of games and discovery learning models accompanied by audio-visual media can improve scientific literacy (Niswatuzzahro et al., 2018). Visualization of material through teaching materials installed on smartphones facilitates the arrival of information from teaching materials to students which has an impact on increasing scientific literacy (Albab & Wijiastuti, 2018). In addition, images and game animations in teaching materials can attract students' interest in learning effectively which has an impact on increasing the achievement of learning objectives (Albab & Wijiastuti, 2018; Ifenthaler et al., 2012).

Tabel 6. The average acquisition of students' scientific literacy scores in each meeting and N-Gain analysis

Meeting	Pre-Test				Post-Test				N-Gain			
	Control		Experiment		Control		Experiment		Control		Experiment	
	Mean	Criteria	Mean	Criteria	Mean	Criteria	Mean	Criteria	Score	Criteria	Score	Criteria
I	34,78	VL	26,67	VL	55,07	L	62,67	M	0.19	L	0.43	M
II	28,99	VL	9,33	VL	33,33	VL	34,67	VL	0.04	L	0.27	L
III	14,78	VL	36,00	VL	24,35	VL	72,80	H	0.02	L	0.56	M
IV	35,07	VL	50,67	L	42,03	L	85,33	VH	0.07	L	0.76	H
Average	28,41	VL	30,67	L	38,70	VL	63,87	M	0.08	L	0.51	M

Annotation: VH (very high), H (High), M (Moderate), L (Low), VL (Very Low)

The significance of the difference in scientific literacy learning outcomes between the experimental class and the control class using inferential statistical tests. Parametric inferential statistics require prerequisites for their use (Table 7). Confirmed pretest data do not meet the requirements of normality and homogeneity due to obtaining output sig. (p) < 0.05 on the Shapiro-Wilk test and One way ANOVA (Table 7). On the other hand, the posttest data confirmed to meet the requirements of normality and homogeneity due to obtaining output sig. (p) > 0.05 (Table 7). Sujarweni and Utami stated that data is said to be normal and homogeneous through the Shapiro-Wilk test and One way ANOVA if the sig. (p) > 0.05 (Sujarweni & Utami, 2019). Based on the prerequisite tests that have been carried out, the pretest data used the Mann-Whitney non-parametric test and the final test data used the Independent T-test parametric test.

Table 7. Data analysis of inferential statistical prerequisite tests and hypothesis testing of the difference in scientific literacy Scores between the control and experimental classes

Variance	Df	Homogeneity	Normality	Inferential statistic	
		One Way ANOVA (Sig. (*p*))	Shapiro-Wilk Sig. (*p*)	Mann Whitney (Sig. (*p*))	Independent T-Test (Sig. (*p*))
Pretest control-experiment	48	0,006	0,004	0,188	-
Posttest control-experiment	48	0,589	0,145	-	< 0,001

The significance level of the effect of using BANDI on scientific literacy was confirmed through the Mann-Whitney statistical test and independent T-test. The results of the Mann-Whitney analysis on the pretest showed that the probability value was much greater than alpha (0,05), and the independent T-test analysis on the posttest obtained a much higher probability value that was smaller than alpha (0,05) (Table 7). The probability result value describes that there is no significant difference between the control class and the experimental class at the time of the initial test, but in the final test the control class and the experimental class show a significant difference. Sujarweni and Utami stated that there was a significant difference between the two sample groups through the Mann-Whitney test and T-test if the probability output value was less than 0.05 (Sujarweni & Utami, 2019). Mann-Whitney analysis and T-test confirmed that BANDI had a significant effect on increasing students' scientific literacy scores due to the significant difference in scientific literacy learning outcomes between the control and experimental classes.

Conclusion

Based on the results and discussion, it can be concluded that BANDI has a good performance in improving scientific literacy both in terms of practicality and effectiveness. The practicality aspect was confirmed through the implementation of learning in the very high category and the responses of students and teachers in the very high category. Then the effectiveness aspect was confirmed through N-Gain analysis where the majority of experimental class analysis value was in the moderate category. Furthermore, the effectiveness aspect is proven through hypothesis testing with inferential statistics where there are scientific literacy learning outcomes that are significantly different between the control and experimental classes, where the experimental class has a much higher average score.

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