ICMSE (2024): 139-146
International Conference on Mathematics, Science, and Education
QRCBN 62-6861-0508-697
https://proceeding.unnes.ac.id/icmse

Development of Digital Teaching Materials Based on PBL and Socio-Scientific Issues Content on Fluid Topics to Improve Critical Thinking Skills

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Abstact. Critical thinking skills are one of the 21st century skills that must be mastered. The implementation of the learning process with the Problem Based Learning (PBL) learning model and using Socio Scientific Issues (SSI) content can support the improvement of critical thinking skills and produce meaningful learning. This research aims to determine the characteristics, feasibility, practicality, and effectiveness of teaching materials in improving students' critical thinking skills. This research method is Research and Development (R&D) with the ADDIE approach (Analysis, Design, Development, Implementation, and Evaluation). The results showed that the teaching materials developed were valid and feasible to use to improve critical thinking skills. The instrument used to measure critical thinking skills is a test instrument. The average of N-Gain score obtained by experimental groups 1 and 2 is 0.728. Assessment through the test method shows that the development of teaching materials is effective in improving critical thinking skills.

INTRODUCTIONS

The improvement of educational quality is directly linked to the curriculum that determines the manner in which the educational process is conducted. The current curriculum is the *Kurikulum Merdeka. Kurikulum Merdeka* places an emphasis on freedom, both in terms of learning and creative thinking (Indarta et al., 2022). *Kurikulum Merdeka* places an emphasis on the development of competence and the improvement of character. This is achieved through the implementation of activities based on the *Program Penguatan Profil Pelajar Pancasila (P5)*, which encompasses six dimensions: (1) faith and reverence for God, (2) an appreciation for global diversity, (3) a commitment to mutual cooperation, (4) independence, (5) critical thinking, and (6) creativity. Furthermore, the 21st century presents a multitude of skills that necessitate preparation and training to achieve mastery. As Trilling & Fadel (2009) posit, learners must be equipped with 21st-century skills. One of the most crucial of these is the capacity for critical thinking and problem-solving. A substantial body of research on critical thinking skills indicates that these abilities are essential for attaining learning objectives, particularly in the context of abstract material, where a robust conceptual understanding is necessary. The development of critical thinking skills is a key educational objective for educators (Tosuncuoglu, 2018).

The development of critical thinking skills is facilitated by an aligned learning process. One such method is the implementation of the problem-based learning (PBL) model. The PBL learning model is believed to influence students' critical thinking skills (Pertiwi et al., 2023). The application of this problem-based learning model entails the implementation of learning activities that facilitate problem-solving techniques pertaining to issues encountered

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in everyday life (Putri & Yohandri, 2021). Rachmantika & Wardono (2019)asserted that critical thinking skills are closely related to problem-solving skills. The problem presented must be a problem that requires students to find solutions in accordance with the concepts and theories that have been acquired. The implementation of learning has not demonstrated a significant degree of actualization of material with substance that is closely related to the material in question. The implementation of appropriate and efficacious learning strategies can facilitate students' abilities to socialize, communicate, solve problems, collaborate, and engage in critical thinking. One learning strategy that can be employed is the integration of socio-scientific issues (SSI) into the learning process. The integration of SSI content into the learning process has the potential to enhance students' problem-solving skills (Hanifah et al., 2021). The integration of SSI into the learning process represents a promising avenue for enhancing scientific education (Sadler et al., 2016). Selpiyanti (2022) indicated that SSI problems integrate the moral dimensions of a scientific topic through discussion and learner interaction on controversial issues, with the objective of resolving these issues. Consequently, SSI is an open-ended approach that enables learners to engage in critical thinking about the issues at question, in collaboration with others who may hold disparate perspectives.

Learning media represent a significant component of the learning process. As Junaidi (2019) asserts, learning media represents a crucial element in the teaching and learning process. Learning media serves as both a conduit for knowledge and a tool for educators to disseminate information and materials. Based on interviews conducted with one of the physics teachers at SMA N 1 Kandangserang, the learning process still relies heavily on printed learning media and utilizes learning resources that are relatively limited in variety, largely due to the constraints imposed by the recently implemented curriculum. Furthermore, the results of the student survey indicated that the majority of students desired a more diverse range of learning media, including learning videos and other innovative teaching materials, to support their learning. Furthermore, students expressed a preference for digital learning media, citing its practicality and portability as key advantages. One digital teaching material is the use of flipbooks. The use of flipbooks allows students to access a variety of materials that employ engaging formats, content, and display methods, offering a diverse range of content that can stimulate interest in the learning process (Landina & Agustiana, 2022).

In consideration of the previously outlined issues, a study was conducted with the title "Development of Digital Teaching Materials Based on PBL and Socio Scientific Issues Content on Fluid Topic ti Improve Critical Thinking Skills" the objective of which was to ascertain the effectiveness of the digital teaching materials developed for the purpose to improve critical thinking skills.

RESEARCH METHOD

Participant

The study focused on students in class XI of SMA Negeri 1 Kandangserang during the second semester of the 2023/2024 academic year. The sample was 64 students.

Design and Procedure

This research employs a Research and Development (R&D) approach, namely the ADDIE Model, which is particularly suited to the development of educational products such as teaching materials (Selpiyanti, 2022). The ADDIE stage, as proposed by Robert Maribe Brach and referenced by Sugiyono (2016), comprises five stages there are Analysis, Design, Development, Implementation, and Evaluation.

The analysis stage begins with the observation of SMA N 1 Kandangserang to identify potential issues. Subsequently, the design stage involves the creation of product designs in the form of PBL-based digital teaching materials (flipbooks) and SSI-content on fluid topics. The subsequent stage is development, which entails the creation of media in accordance with the previously designed plans, as well as the validation of the media and instruments through small-scale tests at SMA N 2 Bae Kudus with 30 respondents. The subsequent stage is the

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implementation of the proposed technique, which will be conducted on a large scale at SMA N 1 Kandangserang. The implementation involves two experimental classes, with a total of 64 respondents.

Instrument

The technique, which is referred to as nonequivalent control group design will be applied in the aforementioned classes. The following section provides a detailed explanation of the research design that was employ:

R_{E1}	O_1	X	O_2
R_{E2}	O_3		O_4

Table 1. Nonequivalent Control Group Design

Prior to the administration of the treatment, both classes conducted a pretest to ascertain the baseline proficiency of the students in regard to the subject matter. The subsequent phase of the study entails the administration of distinct treatments to the two experimental groups. The experimental class was provided with a learning media treatment using digital teaching materials based on PBL and SSI content with in the flipbook form. In the second experimental class, the treatment is applied using digital teaching materials based on PBL and SSI content in the printed version. The final stage of the study entails administering a posttest to both classes to ascertain the extent of their comprehension of the physics concepts. The final stage is evaluation. This is conducted through n-gain test, which determines the effectiveness of digital teaching materials to improve critical thinking skills. This is done by comparing the results of the test before and after the students have engaged with the digital teaching materials.

Analysis of Data

The feasibility of media from a media and material perspective is determined by Aiken's V analysis, which employs the following formula (Retnawati, 2016):

$$V = \frac{\Sigma S}{n(c-1)} \; with \; S = r - lo$$

Description:

V: validity index	lo: the lowest assessment rating	c: number of rating categories
r: rating given by the assessor	n: number of raters/validators	

The Vcount result is compared with the Vtable value. If Vcount ≥ Vtable, then the media is declared valid, while if Vcount < Vtable then the media is declared invalid. The Vtable used in this research is 0.8 because this study uses 5 raters.

The Effectiveness of the media to improve student's critical thinking was evaluated using the n-gain test. The normality test and the t-test were conducted as preliminary analyses prior to the n-gain test The n-gain test was calculated in accordance with the formula established by Hake.

$$\langle g \rangle = \frac{\langle Spost \rangle - \langle Spre \rangle}{max\ score - \langle Spre \rangle}$$

Description:
⟨g⟩ : the magnitude of the N-Gain value
⟨Spost⟩ : average post-test score (%)
⟨Spre⟩ : average score of pre-test (%)

The results of the calculation are classified according to the category of the n-gain score as shown in Table 2 (Sembiring & Napitupulu, 2022).

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TABLE 2. Categories of Interpretation of the Effectiveness of the N-gain Score

N-gain Score	Category
$\langle g \rangle > 0.7$	High
$0.3 \leq \langle g \rangle \leq 0.7$	Medium
$\langle g \rangle < 0.3$	Low

RESULT AND DISCUSSION

In order to ascertain the effectiveness of the teaching materials in enhancing students' abilities in critical thinking, two sample groups were subjected to learning activities, namely XI IPA 2 (Experiment 1) and XI IPA 2 (Experiment 2). The learning process was conducted over three meetings, with each meeting comprising three JP (3x45 minutes). The development of students' critical thinking skills was evaluated through the administration of a test. The test method entails the administration of pretest and posttest questions to the students. The objective of administering these questions is to ascertain whether students demonstrate an improvement in their critical thinking skills subsequent to learning fluid material through the utilisation of digital teaching materials based on PBL and SSI content. The improvement of students' critical thinking skills in each sample group is observed through the results of data analysis conducted at several stages with the assistance of the IBM SPSS Statistics program.

In the first stage of the analysis, a data normality test was conducted. The normality test is employed to ascertain whether the pretest and posttest data in each group are normally distributed. Furthermore, the normality test is a prerequisite for conducting the t-test. The results of the normality test of critical thinking skills data, conducted with the IBM SPSS Statistics software, are presented in Table 3.

Table 3. Critical Thinking Skills Data Normality Test Results

Sample Groups	*Sig. Kolmogorov Smirnov*	
	Pretest	***Posttest***
Experiment 1 (XI IPA 2)	0,66	0,200
Experiment 2 (XI IPA 1)	0,200	0,200

The results of the normality test analysis, conducted using the Kolmogorov-Smirnov test, the pretest and posttest values of students' critical thinking skills, showed a significance level greater than 0.05. This indicates that the pretest and posttest data from both sample groups are normally distributed, allowing for further analysis.

The second analysis conducted was a homogeneity test based on the critical thinking skills posttest data from both sample groups. The homogeneity test was conducted as a prerequisite to the t-test. The homogeneity test was conducted using the Levene test with the assistance of the SPSS software, yielding a significance value of 0.361 for the posttest data of the two sample groups. The obtained significance value was greater than 0.05, indicating that the two sample groups in the study exhibited homogeneity or the same variant.

The t-test conducted in this study is the independent samples t-test. The Independent Sample t-test is employed to ascertain the discrepancy in critical thinking abilities exhibited by students in the experimental group 1 and experimental group 2. The results of the independent sample t-test between the two sample groups are presented in Table 4.

Table 4. Independent Sample t-test Results of Critical Thinking Skills

Sample Groups	n	*Mean*	df	t count	sig. (2-*tailed*)
Experiment 1	32	84,96	62	4,386	< 0,01
Experiment 2	32	76,86			

Table 3 reveals that the results of the independent sample t-test between the Experiment 1 and Experiment 2 groups are statistically significant ($p < 0.01$). The obtained significance value is less than 0.05, indicating a statistically significant difference in critical thinking skills between the two groups following the learning process. The existence of this significant difference is then evaluated by examining whether there is an increase in the results

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of critical thinking skills on the pretest and posttest through the Normalized Gain test (N-Gain test) in each sample group.

Prior to conducting the N-Gain test on each sample group, it is essential to perform a Paired Sample t-test to ascertain whether there is a statistically significant difference between the pretest and posttest results within each sample group. The results of the Paired Sample t-test, conducted using the IBM Statistic program, are presented in Table 5.

Table 5. Paired Sample t-test Results of Critical Thinking Skills

Sample Groups	n	Mean	df	t-count	sig. (2-*tailed*)
Experiment 1	32	-56,20	31	-54,26	< 0,01
Experiment 2	32	-47,70	31	-31,14	< 0,01

Table 5 indicates that both sample groups in this study yielded a significance value of less than 0.01. The resulting significance value is greater than 0.05, indicating that there is a statistically significant difference in the average pretest and posttest scores of critical thinking skills between the two research sample groups. In light of the results of this analysis, the N-Gain test was subsequently employed to assess the improvement in students' critical thinking skills. The N-Gain test was conducted using the Microsoft Excel software. The results of the N-Gain test for each sample group are presented in Table 6.

Table 6. Results of N-Gain Test Analysis of Critical Thinking Skills

Sample Groups	Average Value		N-Gain Score	Criteria
	Pretest	Posttest		
Experiment 1	27.93	91.125	0.791	High
Experiment 2	31.64	80.125	0.664	Medium
Average N-Gain Score			**0.728**	

The results of the N-Gain test analysis are presented in Table 5, which demonstrates that the average N-Gain score for experimental class 1 is higher than experimental class 2. The experimental class 1 sample group utilizes digital teaching materials based on PBL and SSI content in the form of flipbooks, whereas the other experimental class employs digital teaching materials based on PBL and SSI content in printed version. The sample group that engaged in learning with digital teaching materials in the form of flipbooks exhibited an increase in the high category. The sample group that engaged in learning with digital teaching materials in a printed format exhibited an increase in the medium category. These findings suggest that digital teaching materials in the form of flipbooks may be more effective ti improve critical thinking skills.

Further analysis is required to determine whether the observed increase between experimental group 1 and experimental group 2 was reflected in all critical thinking skills indicators. The indicators of critical thinking skills utilized in this study are as follows: The following indicators of critical thinking skills were considered: (1) focusing questions, (2) analyzing questions, (3) asking and answering about a challenge or explanation, (4) considering the accuracy of the source, (5) observing and considering observation reports, (6) deducing and considering the results of deduction, (7) inducing and considering the results of induction, (8) making and considering the results of decisions, (9) identifying terms, (10) identifying assumptions, (11) deciding on an action, and (12) interacting with others. The results of the N-Gain score analysis on each indicator of critical thinking skills measured in the study are presented in Figure 1.

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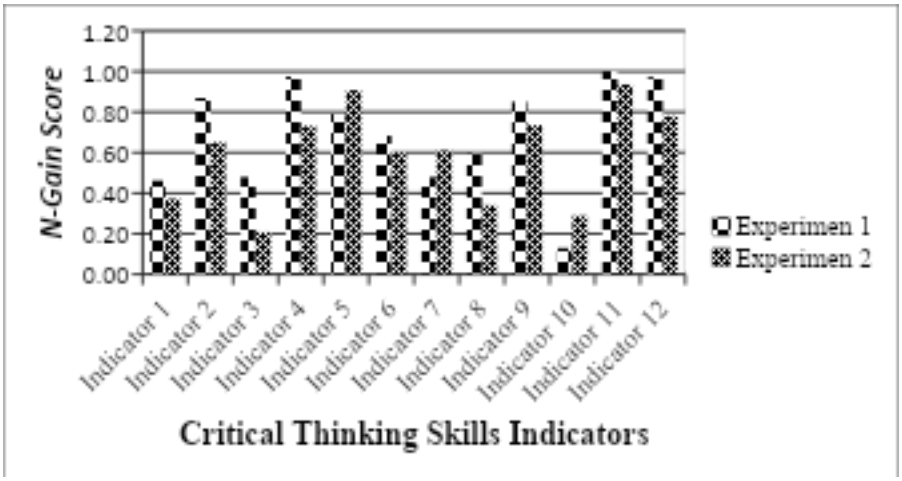

FIGURE 1. N-Gain Score Analysis on Each Inidcator

As illustrated in Figure 1, there has been a statistically significant increase in students' critical thinking skills across all indicators and sample groups. The experimental group, which engaged in learning through the use of digital teaching materials in the form of flipbooks, demonstrated a notable increase in each indicator. This increase, when compared to that of experimental group 2, still dominates in each indicator, although there are several indicators for which the increase is greater in experimental group 2. Each indicator in the study was measured by two multiple-choice questions and two essay questions, representing each aspect of critical thinking skills.

The findings of this study suggest that the printed version of digital teaching materials exhibited a comparatively lower increase than digital teaching materials in the form of flipbooks. This result contrasts with the results of the analysis conducted by Pramita et al. (2021), which indicated that printed teaching materials are more effective in improving students' critical thinking skills, particularly in terms of understanding learning materials. The improvement in students' critical thinking skills when learning with the printed version of digital teaching materials persists, although it is slightly less pronounced than with the flipbook format. Although digital teaching materials possess a greater number of attractive features, the majority of learners exhibit a greater preference for the printed version of teaching materials due to its capacity to facilitate reading and exploration (Kisno & Sianipar, 2019). This is why, in several indicators, such as asking and considering observation reports, inducing and considering the results of induction, and identifying assumptions, the group using the print version of digital teaching materials has a higher level of improvement. This is because the two indicators require focus and also deeper analysis. In contrast, digital teaching materials may prove distracting for students due to the numerous activities that must be accessed and completed.

CONCLUSION

The digital teaching materials, which had previously been developed and declared feasible, were then tested on the learning of physics at SMA N 1 Kandangserang. This involved the involvement of two classes, which were selected as sample groups for the purposes of this experiment. Experiment 1 employed digital teaching materials in the form of flipbooks, whereas experimental group 2 utilized printed versions of digital teaching materials with content accessed via QR codes. The effectiveness of the teaching materials was evaluated through the administration of pre- and post-test questions to the students. The increase in N-Gain for experimental class 1 was 0.791, while that for experimental class 2 was 0.664. In experimental class 1, a higher N-Gain score was obtained for indicators 1 (focusing questions), 2 (analyzing questions), 3 (asking and answering questions), 4 (considering the accuracy of the source), 6 (deducing and considering the results of deduction), 8 (making and considering the results of decisions), 9 (identifying terms), 11 (deciding on an action), and 12 (interacting with others). In Experiment 2, the N-Gain score was higher for indicators 5 (observing and considering the observation report), 7 (inducing and considering the results of induction), and 10 (identifying assumptions). The findings of the analysis indicate that the digital teaching materials utilized effectively enhance students' abilities in critical thinking.

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