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# Development of Problem-Solving-Based Science Teaching Materials to Improve Students Critical and Logical Thinking Skills

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**Abstract**

This research innovation is developing problem-solving-based science teaching materials that can help students solve problems in daily life and science and teaching materials can be tested for feasibility. This research is an important step in providing innovation in the development of science teaching materials and forming changes in the form an increase in students critical thingking and logical thingking skills. This research aims to develop problem-solving-based science teaching materials to improve the critical thinking and logical thinking skills of the learners. This Research & Development adopted Sugiyono's model. The research design used was one groups pretest-posttest design with the member of subject were 58 students. The data collection techniques were interview, test, and questionnaire. The results of the interview show that there is a need for innovation in the development of science teaching materials. The results based on tes show that the problem-solving-based science teaching materials influenced the critical thinking and logical thinking skill improvements with the classical accomplishment 89%. The N-Gain score is 0.70, categorized high. The results based questinnaire show the teachers' responses were 100% considered the material was very excellent. The results of the learners' responses showed a percentage of 96.75% considered the material was very excellent. The content reliability, validity, display, and graph obtained a percentage of 86.54%, categorized as very reliable. Thus, the problem-solving-based teaching material was reliable for the learners to solve the lesson related to daily life. It could also improve the critical thinking and logical thinking skills of the learners.

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## INTRODUCTION

The concept of autonomous learning is the alternative to develop the 21st skill to solve problems. The ministry of education and culture mentions that autonomous learning is the freedom to think. It expects learners to freely think and find knowledge with their thinking skills (Yamin & Syahrir, 2020). Supportive learning to develop 21st century learning is problem-solving (Hendri, 2020). One of the problem-solving strategies is to create classroom learning that could develop the learners' critical thinking skills.

Critical thinking skills allow is very crucial due to it's benefit to individuals in making a decision, analyze problems, and overcome the encountered problems (Walfajri & Harjono, 2019). Teachers have roles to foster critical thinking skills by providing an encouraging lesson for learners to think. Thus, teachers need an effective learning strategy that allows critical thinking skill improvement with problem-solving (Umuroh & Agoestanto, 2016). Critical thinking skills require learners to conclude, solve problems based on the notion and ideas and share the reasons (Amalia & Pujiastuti, 2016). Critical thinking skills and problem-solving skills are useful to obtain knowledge of important concepts (Susilo, 2012). The influence of critical thinking skills is observable from the improved learners' learning motivation (Cholisoh et al., 2015).

Not only critical thinking skills, logical thinking skills are also important for learners as the preparation to engage with the 21st century (Anriani & Pamungkas, 2019). The logical thinking ability of students needs to be trained so that students are accustomed to using these abilities. Critical thinking skills require basic knowledge based on the experience of learners (Surat, 2016). The logical thinking skill requires problem-investigation activity to stimulate the learners. Therefore, it is necessary for the teacher's role and effort to motivate, train and explore all logical thinking skills and knowledge of students, one of which is problem investigation activities.

The learners' logical thinking skill also needs teaching materials as the material source. Through teaching materials, the activities and creativity of students in learning can be improved, the delivery of subject matter can be made easier by using teaching materials and can encourage students to learn to understand (Syafei, 2019). Learners who could develop logical thinking skills tend to be academically successful (Candrawati & Hidayati, 2017). The ability to think logically is also influenced by the conditions of group discussion activities. One of group learning that can be used is problem-solving-based. Students in solving daily problems correctly will be trained and able to develop logical thinking skills in the scope of students' lives. Problem-solving skill is a potency of an individual in his daily life (Nurfatanah et al., 2018).

The 2013 curriculum is oriented toward student-centered learning are also establishes lesson that encourages learners to undergo some processes. It stimulates them to think critically, to have the capability, and to have skills. This fact demands teachers to be more creative in promoting the classroom teaching-learning process. One of the lessons taught in a classroom is science. Science is taught with an effective learning process that provides excellent understanding so as learners can apply in real life (Walfajri & Harjono, 2019). The science learning process should facilitate and encourage learners to think critically, logically, and systematically (Ramdoniati et al., 2018).

Teachers can have the alternative by composing science teaching material to facilitate them creating attractive and innovative learning situations. Teaching material is useful for learners to learn better and facilitates teachers to motivate, train, and elicit the learners' skills and cognition. The development of teaching material is a learning process to improve the learning quality (Nurbaeti, 2019). Thus, the developed science teaching material is to meet the learners' necessities in learning to reach the science lesson that fosters environmental awareness attitude.

The teaching materials should refer to the teaching materials, learners' needs, novelty,

contemporariness, and better values. Science learning should connect the environment, community, and technology. Thus, learners will not only understand the science aspect but also the application in daily life (Farda et al., 2016). The problem-solving-based science learning development is based on the 2013 curriculum with thematic lesson and energy resource and conversion as the topic.

This research aims to (1) find out the validity of the developed problem-solving based science learning teaching material to improve the critical thinking and logical thinking skills, (2) describe the effectiveness of the model to improve the critical thinking and logical thinking skills, (3) describe the reliability of the teaching material to improve the critical thinking and logical thinking skills.

The theoretical implications as a reference to develop the problem-solving-based science teaching material on energy resource and conversion at primary school education to be effective and efficient. The practical implications are teachers could use the teaching material as a reference and recommendation to optimize science learning. Their learners could use the teaching material to improve their critical thinking and logical thinking skills.

## METHOD

This Research & Development adopted Sugiyono's model. The researcher used Sugiyono's adapted procedures that had eight stages. They were (1) finding potentials and problems, (2) collecting data, (3) designing the product, (4) validating the design, (5) revising the design, (6) testing the product, (7) revising the product, and (8) trial the product.

At the first stage, finding potentials and problems, the researcher interviewed the teachers to find the problems of the science learning process. The data collection technique was to identify the needs and problems at school. The product design was composing the science teaching material based on the 2013 curriculum. The researcher also used problem-based learning with an interesting package and understandable language.

The validation stage dealt with the developed teaching material reviews by the experts. They were experts of content, teaching materials, and practitioner. The testing product stage allowed the fourth graders of Public Primary School Sido Gede at Belitang district, consisting of 22 learners, to try the product. It had the purpose to validate the readability of the teaching material and the validity of the questions. Then, the researcher revised and improved the teaching material at the product revision stage. At the last stage, the trial run of the product, the researcher involved 36 fourth graders of Public Primary School Sidomakmur at Belitang district. The researcher passed the response questionnaire after the learners used the teaching material. The researcher also conducted a test with question items to check the critical thinking and logical thinking skills of the learners.

The applied techniques were interviews, to obtain the initial data and identify the science learning problem; documentation to observe the previous teaching material; tests to check the learners' critical thinking and logical thinking skills, and questionnaires to obtain the data of the teaching material effectiveness. The obtained data were qualitative and quantitative data.

The applied data analysis technique was descriptive analysis. The collected data were classified into two groups. They were qualitative and quantitative data. The qualitative data dealt with words while quantitative data dealt with numbers. The qualitative data were useful to complete the obtained description. Then, the descriptive quantitative data were useful o process the obtained data via questionnaire, checklist, and categorization based on the applied instruments. The quantitative data analysis was useful to count the validity level of the teaching materials, the readability, the effectiveness, and the reliability.

## RESULTS AND DISCUSSION

### The Teaching Material Validity

The developed teaching material took the topic of energy resources and their conversion for the fourth graders of Primary School. The structures of the developed teaching material were (1) cover, (2) preface, (3) table of contents, (4) direction, (5) core competencies and indicators, (6) mind-map, (7) materials, (8) Ayo Berfikir, (9) Ayo Diskusi, (10) Ayo Kita Lakukan, (11) Information about science, (12) Glossary, and (13) Bibliography.

The initial design of the product was validated by content and media experts. The validation process involved two lecturers as the experts and a teacher as a practitioner. The judgment of the teaching material showed that the teaching materials had met the indicators applied by the National Education Standardization Institution. The recapitulation of the judgment percentage by the experts are displayed in Table 1.

**Table 1.** The Validity Test Results

| The Judgment Aspect | Percentage | Criteria |
|---|---|---|
| Content Material Expert | 87.14% | Very Valid |
| Media Expert | 91.67% | Very Valid |

Table 1 shows the validity of teaching material is valid. It proves that the validity test of each judgment aspect indicator reaches the average category of very excellent. The content material validation result reached the valid category. It meant the product could be tested in the schools, in terms of the content, presentation, language, and problem-based learning aspects. The validation result of the media expert obtained a very valid category. The validity result had the function of an attempt to make the teaching material excellent and relevant (Sistyarini & Nurtjahyani, 2017).

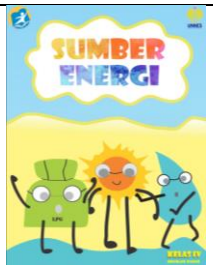
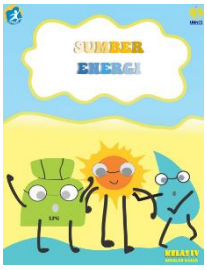
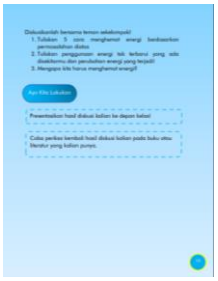
The readability, based on the learners, obtained a very high category. The initial stage of development of the teaching material had undergone a limited test. It was to check the teaching material's readability. The limited test was only for learners. They had to provide their judgment in the questionnaire. The judgment consisted of the display, easiness, and usefulness aspects. The results of the judgment became a recommendation to revise the product.

In general, the teaching material had met the validity category. However, the researcher conducted a minor revision based on the suggestions of the experts and the readability questionnaire of the learners. The revisions were (1) revising the title on the cover, (2) adding the detailed conceptual map, (3) adding reference and the subject material, and (4) adding the practices and questions. The researcher did this to ensure the product could be used properly.

The book, as the teaching material, was useful to support the material delivery. The package of the book was only one complete book. It allowed teachers to reach the learning objectives. The science teaching materials were completed with problem-solving-based learning to influence the learners' cognitive skills. Problem-solving-based learning provides opportunities for learners to solve problems along with their cognitive skills (Winoto & Prasetyo, 2020).

The product used an attractive design for the learners. The bright color was useful to attract the learners' attention. Thus, learners would be motivated to read the teaching material. It proved that the developed teaching material had already had clear figures and writing. They were printed colorfully, uniquely, and interestingly. Teaching material is suitable for visual learning (Sari et al., 2019). Thus, it must be designed attractively to motivate learners to read and understand the teaching material. The revision of the product is in Table 2.

**Table 2.** The Pre and Post Revision of the Teaching Material Development

| | | | | |
|---|---|---|---|---|
| Before the revision |  |  |  |  |
| After the revision |  |  |  |  |
| The suggested revisions | Revising the title on the cover and making the fonts thinner | Revising the conceptual map to be more competitive and detailed | Revising the irrelevant materials and adding some materials | Enriching with more practices and questions |

**The Effectiveness of the Teaching Material**

The teaching material that has been tested for reability is then tested for the product trial stage. The test was to find out the effectiveness of the developed teaching material. The product trial run was for the fourth graders of Public Primary School Sido Gede. The following is an example of an answer to a pre-test product trial in a group of students in science subjects with problem-solving-based learning to improve logical thinking and critical thinking skills are displayed in Figure 1.

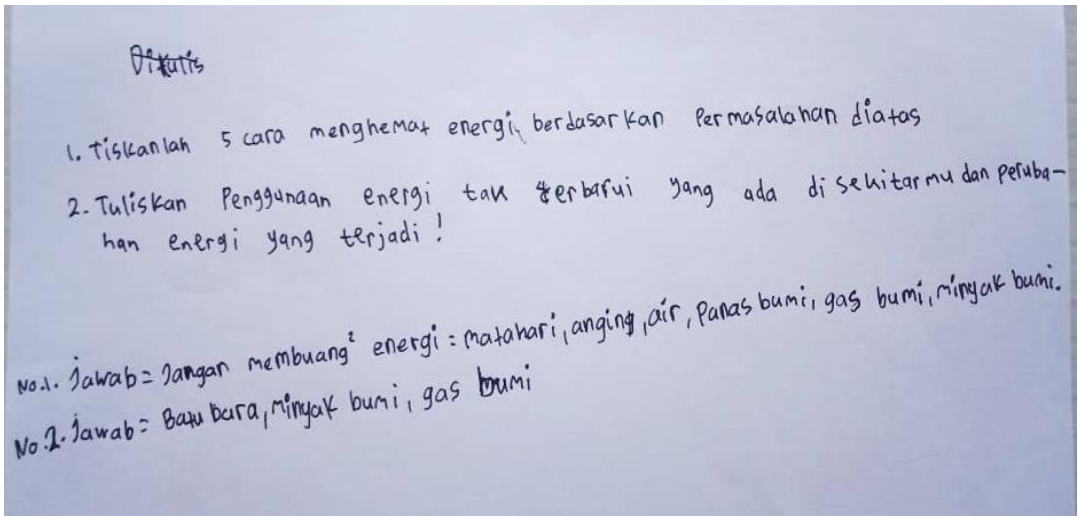

Diketahui
1. Tiskanlah 5 cara menghemat energi berdasarkan permasalahan diatas
2. Tuliskan Penggunaan energi tak terbarui yang ada di sekitarmu dan perubahan energi yang terjadi!
No.1. Jawab = Jangan membuang² energi : matahari, anging, air, Panas bumi, gas bumi, minyak bumi.
No.2. Jawab = Batu bara, minyak bumi, gas bumi

**Figure 1.** Sample of student's answer during pre-test

Figure 1 shows that the answers of students in critical thinking indicators, namely and providing further explanations and grouping by type are still not visible. This can be seen with students giving short answers and not providing information on each answer given. Students are also not able to determine the activities that should be done and not done in saving energy sources. In the logical thinking indicator, the reasoning needed to provide conclusions has not yet been seen, this can be seen in students still providing answers to the second item who do not recognize examples of energy changes in the surrounding environment. The following is an example of an answer after a product trial test in a group of students in science subjects with problem-solving-based learning to improve logical thinking and critical thinking skills are displayed in Figure 2.

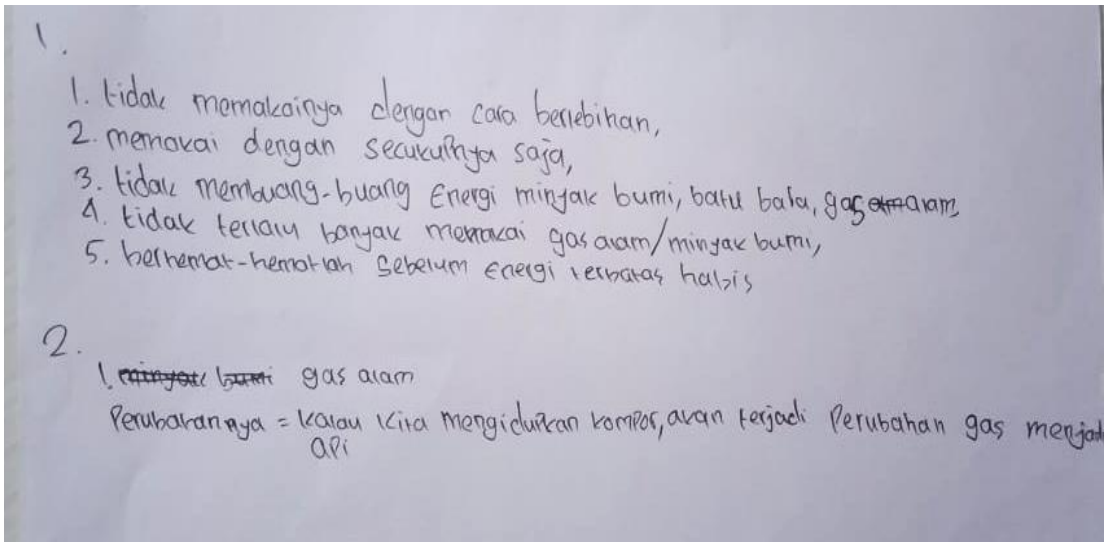



**Figure 2.** Sample of student's answer during posttest

Figure 2 shows that students correctly answered all the items according to the questions given. The answers given by students show that students understand better in characterizing ways to save energy, are able to provide reasoning and conclusions about energy changes that occur around the environment. The improvement of posttest learning outcomes is based on indicators of critical thinking skills and logical thinking. This improvement is supported by the use of problem-solving-based science teaching materials.

The classroom learning was considered successful if a percentage of 75% of learners reached the classical minimum completion. The classical completion results after the posttest it reached with 89% completion category. The classical learning completion of learners showed that their understanding of energy resources and their conversion was excellent. It showed that the developed teaching material was understandable for them. Thus, it could improve their critical thinking and logical thinking skills.

The critical thinking and logical thinking skill improvements of the learners could be obtained from the pretest and posttest scores. The improvement was calculated with the N-Gain formulaThe learning analysis results showed significant improvements between the pretest and posttest results. The evidence was the N-Gain test result that reached 0.7, categorized high. The improvement showed the learning activity with the developed teaching material could improve the learners' skills (Febrianti et al., 2015). The implementation of problem-based learning was in line with Science learning characteristics, by emphasizing the process and the product (Widiastuti et al., 2018). The learning process proved the learners' skills were improved.

The teaching material development could also improve the learners' critical thinking skills.

With critical thinking skills, learners could decide to solve problems. Critical thinking skills are important for learners to be skillful in observing, reviewing, and solving various problems (Dewi et al., 2018). An individual's cognitive skill influences learning skills, speed, and effectiveness. Therefore, cognitive or thinking skills are remarked as a learning process. Learners that receive thinking or cognitive training perform a positive effect on their educational development (Jannah et al., 2018). Problem-based learning takes problems and events from the surrounding environment of the learners. It is possible with problem-based materials from the learners' environment. Thus, they can be more interested and enthusiastic (Wardani et al., 2019).

Critical thinking skills provide accurate direction of thinking and performing. It facilitates to determine a relevance of an object to the other accurately. The critical thinking skill is an important skill for learners to trigger their cognitive reasoning and construct knowledge (Adeyemi, 2012). Therefore, the critical skill development of learners must be developed as early as possible.

The critical thinking skill process occurs frequently inside of the mental activity. It has the function to solve problems, make a decision, and seek understanding. Teachers could prepare the educational success by focusing on critical thinking skill development. This skill allows learners to think analytically, communicate effectively, and solve problems efficiently (Živkovic, 2016). Critical thinking skills facilitate learners to solve problems creatively and effectively (Jeronimo et al., 2020).

There is five critical thinking skill framework, according to Ennis, cited in (Prayogi & Asy'ari, 2013). They are 1) providing the elementary clarification, 2) constructing the basic support, 3) inferencing, 4) creating advanced clarification, and 5) applying the strategy and tactic. The indicators of critical thinking skills are in Table 3.

**Table 3.** The Indicators and Sub-Indicators of Critical Thinking Skills

| Indicators | Sub-Indicators |
|---|---|
| **Providing the elementary clarification** | Analyzing the arguments |
| **Constructing the basic support** | Answering an explanation or a challenge |
| **Concluding** | Inducing and considering the results |
| **Providing advanced explanations** | Defining the terms and considering them |
| **Arranging the strategy and tactic** | Grouping based on the types of features |

The teaching material development could also improve logical thinking skills. The learners were expected to be able to conclude each classroom lesson and outdoor activity logically. The developed teaching material was useful to motivate the learners' learning and to develop their logical thinking skills.

The importance of activity in making a decision, drawing a conclusion, and solving problems (Octaria, 2017). The activity realization might involve mathematics problems or other daily life problems. The logical thinking skill at primary school levels had some features. They were such as creating conclusions and proving the truth of the conclusion based on the prior experience of the learners (Widyastuti & Pujiastuti, 2014).

There were three logical thinking skill indicators. They were (1) concept, (2) decision, and (3) reasoning. They are the preconditions of logical thinking skills and are united with each other (Ratna, 2015). They have a structural connection in terms of form and process of validating the cognitive conclusion. The indicators of thinking logically are in Table 4.

**Table 4.** The Indicators and Sub-Indicators of Logical Thinking Skills

| Indicators | Sub-Indicators |
|---|---|
| **Concept** | The results of catching the ideas from an object |
| **Decision** | The idea formulation into statements |
| **Reasoning** | Drawing conclusion from the idea or information |

The following is an example of an answer to a pre-test product trial in a group of students in science subjects with problem-solving-based learning to improve logical thinking and critical thinking skills are displayed in figure 1The teachers' responses toward the teaching material dealt with the reliability, the display, and the language aspects. In general, the teacher perceived the teaching material as very excellent. It meant the teacher responded positively toward the developed teaching material. The presented materials and the relevant figures from daily life facilitated the learners to understand and facilitate teachers to reach the learning objectives (Nurrita, 2018). The use of modest language and the attractive figure display could direct learners to understand the material explanation (Setyowati et al., 2013).

The learners' responses toward the teaching material had three aspects, such as display, easiness, and usefulness aspects. The responses of the learners showed the category of very excellent. It means the learners positively responded to the developed teaching materials on the topic of energy sources and their conversion. An excellent teaching material refers to teaching material that could provide positive responses from the learners in terms of attractiveness. The teaching material should also facilitate learners and make learners understand the material (Febrianti et al., 2015).

The learners' responses toward the display aspect showed the very excellent category. It proved that the developed teaching material display was interesting. The teaching material display with accurate illusion could explain the materials. It had an excellent printed quality and presented attractive figures to motivate learners to read. It also could create a joyful learning atmosphere (Nurrita, 2018). Teaching material must contain supportive figures to clarify the material content (Handoko et al., 2016). It is also useful to attract and lose the boredom of the learners.

The learners' responses toward the easiness aspect showed a very excellent category. It proved the developed teaching media used communicative language for the learners. (Magdalena et al., 2020) state that the use of modest, brief, clear, and effective language in a teaching material could make learners more understand the content. The learners' responses dealing with the usefulness showed a very excellent category. The learners felt the teaching material could enrich their insight about energy resources and the conversion. The teaching materials consist of phenomena and events related to daily real life. These matters motivated the learners to solve the problems in their surrounding environment.

**The Reliability of the Teaching Material**

The reliability instrument consisted of the assessed components published by the National Education Standardization Institution (2007). The reliability components were content validity, such as the material and core competence relevance; the accuracy of the materials; the supplementary materials; and the encouragement for learners' curiosity. The display included the presenting technique, the display support, the material presentation, and the display completeness. The validity consisted of the relevance of the learners' development levels, communication, briefness, grammatical appropriateness, term uses, symbol, and icon. The graph includes the size, the teaching material cover design, and the content design. The calculation results of the product reliability are in Table 5.

**Table 5.** The Reliability Aspect Result of Science Teaching Material

| The Reliability Aspect | Percentage (%) | Criteria |
|---|---|---|
| **Isi** | 76.85 | Very Reliable |
| **Language** | 82.29 | Very Reliable |
| **Display** | 95.37 | Very Reliable |
| **Graphic** | 91.67 | Very Reliable |
| **Average** | 86.54 | Very Reliable |

Table 5 shows all calculations of the developed teaching material validity. The result shows the content reliability is valid. It was because the presented concepts in the teaching materials were adjusted with the core competence, the basic competence, and learning indicators. In this aspect, the content of the teaching material required the content material arrangement to be adjusted with the 2013 curriculum. Besides that, the content material arrangement could make the learners reached the targeted core competence. The content of the teaching material had to consider the relevance with the mastered competencies (Prasetiyo & Perwiraningtyas, 2017).

Besides that, the material display of the teaching material was correlated with some disciplines to enrich the insight of the learners. The science delivered in the teaching material consisted of energy resources and conversion. The developed teaching materials were entailed with problem-solving-based learning. It could develop critical thinking skills and make the learners active in learning because the discussed materials were about life problems (Prasetyo & Kristin, 2020).

The display reliability aspect showed a very excellent category. It proved that the display of the developed teaching material considered the display and figure presentation. thus, the abstract material could be explained interestingly and was easy to understand (Alvian et al., 2017). Besides that, the used sentences were not long and did not use small fonts. Thus, learners were interested to read the teaching material (Utariyanti et al., 2015).

The teaching material display contained a joyful nuance by using attractive figures and graphs. They could encourage learners to elicit more information. The developed teaching material could facilitate them not to depend on the textbooks (Kusumam et al., 2016). The obtained benefits for the learners were creating interesting learning, motivating learners, reducing the dependency, and facilitating the learners to learn each indicator.

The validity reliability aspect showed a very excellent category. It showed that the use of language was correct and adhered the good grammar. The applied language used consistent dictions, and understandable and communicative language. The use of understandable language allowed learners to learn autonomously (Nilasari et al., 2016). Teaching material can facilitate learners to understand the materials better and encourage them to learn and understand autonomously (Syafei, 2019).

The sentence arrangements of the teaching materials adhered to General Guidelines for Indonesian Spelling, for example, the uses of a capital letter, punctuation, and italic font style to show foreign or scientific terms. The paragraphs in the teaching material are not long or short. Thus, learners felt comfortable when they read the teaching material (Fajarini et al., 2016).

The validity aspect of the graph was very excellent. It was observable from the size, the cover design, and the material of the content design. The cover of the teaching material had bright colors and used cartoon figures that learners liked. The color was also an important component in displaying the learning sources (Sulistiyawati & Hedianti, 2015).

Developed teaching material would be reliable to use if the teaching material had been validated by experts of media and material and in line with the National Education Standardization Institution (Muqodas et al., 2015). In this research, the indicators from the National Education Standardization Institution were modified. The results were the relevance of teaching materials with the characteristics of the

teaching material. The high score of the teaching material was due to the development process paid attention to the development principles. They were relevance, consistency, and adequacy principles. the applied teaching material must meet all criteria to support the qualified education. Thus, the teaching material could be used as a reliable learning resource.

## CONCLUSION

The problem-solving-based science teaching material, with the topic of energy resources and the conversion, was valid and easy to understand, based on the teaching material's readability aspect. The teaching material was effective to improve the critical thinking and logical thinking skills of the learners. The signs were observable from the learners' and teachers' positive responses. Thus, the developed teaching material was reliable to use in the class.

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