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Development of STEM-Based Chemistry Textbooks to Improve Students' Problem Solving Skills

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Abstract

This study aimed to develop STEM-based chemistry textbooks on reaction rate topic, in order to improve students' problem solving skills. Textbooks are developed using the Research & Development (R&D) scheme with feasibility indicators seen from the validity and effectiveness of textbooks. The developed textbook was then tested using a one group pretest-postest design research, where the research subjects were 30 students of class XI at SMA Wachid Hasyim 1 Surabaya. The research data were obtained from expert validation sheets and student problem solving skills test sheets. Based on the research conducted, it was found that 1) the textbook developed had a validity score of 3.70 and was categorized as very valid, 2) the increase in student problem solving skills classically obtained was 0.75, in the high category, 3) the percentage of completeness a test of student problem solving skills by 90%, so that STEM-based textbooks can be state to be effective in improving students' problem solving skills. Based on these results, it can be conclude that STEM-based textbooks developed feasible to improve students' problem solving skills.

Keywords: textbooks of chemistry; STEM; problem solving skills

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INTRODUCTION

The world is constantly changing, from geographical conditions to the social order of the earth's inhabitants. The social order, which has also undergone this change, has an impact on global competition between humans, where technology is an important aspect that must be mastered by individuals. In the global competition, individual that can continue to compete, it must have the relevant skills of his time. As mentioned by Wagner (2010), one of the relevant skills in the 21st century includes problem solving skills. In addition, efforts to develop problem-solving skills are consistent with efforts to explore one's potential (Law of the Republic of Indonesia number 20 of 2003). Problem solving skills are also an important aspect, because with these skills, students can be helped to make decisions more precise, careful, systematic, logical, and consider various points of view (Paidi, 2011). Someone is said to be a good problem solver, if he can identify 1) the problems that occur; 2) possible obstacles faced in the problem solving process; and 3) possible solution plans that can be successful (Mahanal, 2019). Experts have mixed opinions regarding indicators of problem solving skills. Yuriev et al (2017) stated that there

are 5 indicators in problem solving skills, namely 1) understanding (understanding the problem), 2) analysis (analyzing problems), 3) planning (planning alternative solutions to problems), 4) implementation (implementing problem-solving plans), and 5) evaluation (evaluating the problem solving done). However, based on the results of the PISA survey (2018) in which there is also a component of student problem solving skills, it shows that 70% of Indonesian students are unable to reach level 2 in the PISA framework. whereas on average only about 23% of students in the 79 PISA participating countries were unable to master level 2 reading skills. This shows that Indonesian students' literacy, which also includes problem-solving skills, is still very low.

In addition, research conducted by Trilling & Fadel (2009) states that some high school, diploma, and tertiary education graduates still lack the skills in the world of work, including problem solving skills. This is reinforced by a study conducted by Nikat & Latifah (2018) which shows that the problem solving index owned by some students is still below 75%. Based on existing phenomena, teachers need to formulate a learning method that supports individuals in order to become familiar with problem-solving skills, including in chemistry learning.

Chemistry learning is one of the important lessons in everyday life. Chemistry is the central of science where chemistry is one of the basic sciences , technology, and industry so it is very important to study (G. Mahdi, 2014; Chang etc, 2011), where the rate of reaction is one of the topics discussed in it. The topic of reaction rates is an important topic in learning chemistry, this is because reaction rate is a material that is fundamental in chemistry (Sari etc., 2018). In addition, the topic of reaction rate is also the key for students in understanding the concepts of other chemistry topics, such as only the concept of thermodynamics (Kaya & Geban, 2012). However, research conducted by Febriani & Ismono (2020) shows that 75% of students still find it difficult to materialize reaction rates. This is reinforced by the results of the pre-research on learning completeness of 25 students on the reaction rate material, showing a percentage of completeness that is less than 60%. According to Sari et al (2018), the difficulties experienced by students in reaction rates are because students cannot connect the relationships between concepts in the topic of reaction rates. Therefore, it is necessary to have a learning management that can support students in reaction rate topics.

One of these ways is by managing chemistry learning using the STEM approach. STEM stands for Science, Technology, Engineering, and Mathematic. According to Torlakson (2014), the combination of these four aspects is a very harmonious combination in responding to problems that exist in the real world and their solutions. STEM-based education itself is a learning that integrates science, technology, engineering and mathematics to develop student creativity in the process of solving problems in everyday life (Winarni etc, 2016). According to Firman (2016) STEM-based chemistry learning is learning the subject matter of chemistry in which it is integrated with the system designs and the use of technology for solving real problems. In addition, STEM-based education and the skills demands of the 21st century have the same goal, namely that students have scientific and technological literacy that is reflected in reading, writing, observing, as well as being able to develop skills that are already owned to be used in overcoming problems of everyday life related to the STEM field of science (Bybee, 2013). In addition, research conducted by Widayoko (2018) shows that there is an increase in

the competence of students' scientific literacy skills using STEM-based teaching materials. Furi etc (2018) in their research also found that there was a significant difference between PjBL and PjBL which was integrated with STEM on students' psychomotor skills and creativity, where PjBL integrated STEM was superior.

STEM-based learning can also make learning carried out by teachers more focused (Gardner etc, 2019). In general, several studies have shown that STEM is an approach to learn which can improve skills, and preparing human resources with capacities in accordance with the demands of the 21st century (Rustaman, 2016; Jamaludin etc, 2017; Jang, 2016), including problem solving skills. Some of the descriptions above, show that this STEM-based learning pattern is closely related to problem-solving skills which are one of the skills demands of the 21st century.

In addition to learn organize problem solving skills, the textbook used must also support the achievement of problem solving skills, because of the availability of good textbooks, it becomes an important component in learning (Asy'ari etc, 2019). One of the concepts of a good textbook, is a textbook that is integrated in STEM and can be used to practice student problem solving skills (Madsen etc, 2016). So based on the description above, it is necessary to have further research related to the development of STEM-based chemistry textbooks on the topic of reaction rates in improving students' problem solving skills.

METHOD

This research was conducted at one of high school (SMA) in Surabaya. Chemistry textbooks developed are only limited to the material on reaction rates topics. The research subjects were students at SMA Wachid Hayim 1 Surabaya class XI with a total sample of 30 students, where the sampling process was carried out randomly.

This research is classified as a development research that uses the Research & Development (R & D) research procedure developed by Sugiyono (2013). This research has the following stages: 1) potential and problems 2) data collection 3) product design 4) product validation 5) product revision 6) limited trial 7) initial product revision 8) final product trial 9) product final revision.

The evaluation of the validity of the textbooks developed was carried out by 4 people, 2 experts in the field of chemistry, 1 expert in chemistry education, and 1 teacher. Validation criteria include criteria for content, presentation, language, graphics, conformance with the STEM component, and conformity with the component of problem solving skills. Each aspect is assessed based on the validity rating scale in Table 1.

Tabel 1. Likert Scale Scoring (Riduwan, 2015)

Criteria	Score
Very good	4
Good	3
Bad	2
Very bad	1

Furthermore, the data validity results were analyzed using quantitative descriptive analysis by calculating the average value given by the validator (P). This score is then described qualitatively by interpreting it according to the criteria in Table 2 as follows.

Table 2. Learning Device Validation Score (Ratumanan & Lauren, 2011)

Score Interval	Score Criteria	Information
3,6 ≤ P≤ 4	Very Valid	Can be used without revision
2,6 ≤ P≤ 3,5	Valid	Can be used with minor revisions
1,6 ≤ P≤ 2,5	Less Valid	Can be used with major revisions
1 ≤ P≤ 1,5	Not Valid	Can't be used

Based on the criteria in Table 2, the textbook developed in this study has a validity indicator, that is, if it is get a score of ≥ 2.6, which meets the minimum valid criteria.

Students problem solving skills are identified at the product trial stage. This product testing uses a one group pretest posttest design, which is research conducted by looking at the differences between the pretest and posttest in the experimental class. The test is used to collect data through tests of problem solving skills in the form of description questions. The test is based on indicators of problem solving competence according to Yuriev et al (2017). Before being used, the problem solving skills test items were validated first to 3 experts and 1 teacher. The results of the validation of the students 'problem solving skills test, both pretest and posttest, got a score of 3.82, so that the problem solving skills test could be declared valid and could be used to measure students' problem solving skills.

The increase in student problem-solving skills is known from the N-gain score data which is first carried out by the normality test with the help of the IBM SPSS Statistics 23 software. The amount of increase or gain is analyzed using the following formula: $\langle g \rangle = \frac{\% < G >}{\% < Gmaks >} = \frac{(\% < Sf > - \% < Si >)}{(100\% - \% < Si >)}$ (Hake, 1999)

Then the results obtained (gain value) are interpreted into categories according to Table 3 as follows.

Table 3. N-gain Criteria (Sudjana, 2012).

Gain Score	Category
>0,7	High
0,7 > g> 0,3	Middle
0,3	Low

Textbooks are declared effective if the majority or more than 75% of users obtain a minimum score of 3.25 with a score range of 1 to 1 to 4 on all problem solving ability test items.

RESULTS AND DISCUSSION

The following are the results of research obtained from the development of STEM-based textbooks, which include product validation, as well as profiles of student problem-solving skills.

Product Validation

Before the STEM-based textbook on the topic of reaction rates was tested on students, 4 validators were first validated, consisting of 2 chemists, 1 chemistry education expert, and 1 chemistry teacher. Validation criteria include textbook organization (including the suitability of STEM components, and allowances in practicing problem-solving skills) the description of concepts (including the correctness of material concepts, as well as compatibility with KD) and appearance. The validation results can be seen in Table 4.

Table 4. Textbook Validation Results

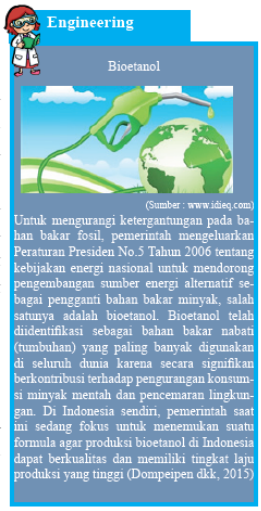
No.	Rated aspect	Score	Average Score
1.	Textbook Organization	3,68	
2.	Concept description	3,55	3,70
3.	Display	3,88	

Based on Table 4, the total average score of textbook validation is 3.70. This makes the textbook developed, when interpreted according to table 2, can be said to be very valid.

The first aspect to be assessed is the aspect of textbook organization. In this aspect, the components assessed include the inclusion of relevant covers / titles, writing of basic competencies and learning objectives, the suitability of the content with the objectives of the curriculum and KD, the breadth of the material, suitability of textbooks with learning, clarity of sources used, clarity of language and sentences, content of textbooks supports student problem solving skills, STEM characteristics in books, characteristics of problem solving skills in books, concept summaries, glossaries, and conceptual understanding questions. This textbook organizing aspect received an average score of 3.68.

This score indicates that the textbook developed is valid and in accordance with the needs in the field. The STEM characteristics that get a valid score make this book usable to support student problem solving skills. This is in line with the opinion of Asunda (2015) which states that textbooks integrated in STEM can support students' problem solving skills. STEM characteristics in textbooks can be seen in Table 5.

Table 5. Characteristics of STEM in Textbooks

Examples of STEM Characteristics in Chemistry Textbooks		
Science	*Technology*	*Engineering*
		

Based on Table 5, it can be explained that this first aspect, which includes the clarity of language and sentences in textbooks can be categorized as valid. This validity category also means that the textbook developed can make it easier for students to understand the material presented. In addition, the ease with which students understand the material can minimize the incidence of misconceptions in students. The ease with which students understand the material in textbooks is

important, because the misconceptions that occur, one of which can be caused by the textbooks used by students (Sulcius, 2014).

The second aspect assessed is the conceptualization aspect. In this aspect, the components that are assessed include the suitability of textbooks with indicators or learning objectives, the correctness of concepts, concept sequences, images that can support the material, and usefulness. The aspect of describing the concept of this textbook gets an average score of 3.75. This average score illustrates that the translation of concepts in textbooks has a valid category.

In the conceptualization aspect, when compared with other aspects in the validation component of this textbook, the conceptualization aspect has the lowest average score, although the validation results obtained are still categorized as valid. This is because in some pictures in textbooks, there are concepts that are not quite right, so they need to be corrected. This improvement can be seen in Figure 1. The aspect of describing concepts in textbooks is an important aspect. The incompatibility of the concept of material in textbooks can cause misconceptions in students (Sulcius, 2014), and results in obstruction of meaningful learning (Suyono, 2020).

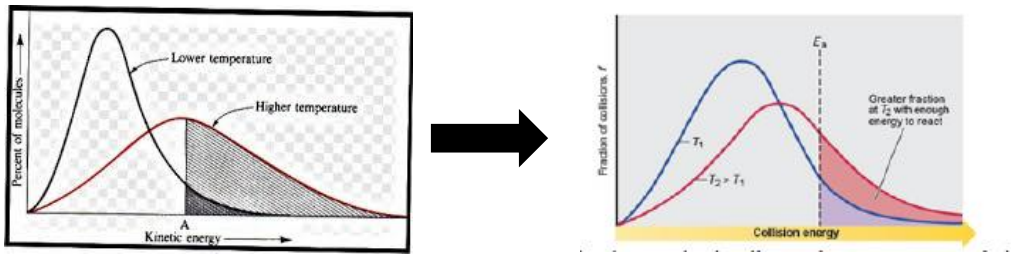


Figure 1. Pictures before revision and after revision, regarding the distribution of kinetic energy for the reaction mixture at different temperatures

Based on the average score on the aspect of conceptualization, it was found that textbooks combined with STEM could support the material and have benefits. This is in line with the research of Asih etc. (2020) which states that the integration of chemical learning in several other fields of science in the STEM project means that chemistry is very closely related to other fields of science, and can be used to motivate students to develop the skills needed in the 21st century. In addition, the order of concepts in books that get a valid score indicates that the textbooks are developed, arranged systematically, and one of the characteristics of a good module (textbook is part of the module) is that it is systematically structured (Lasmiyati & Harta, 2014).

The third aspect that is assessed is the appearance aspect. In this aspect, the components that are assessed including the presentation of text, tables, pictures, accompanied by reference sources, identity tables and pictures, the attractiveness of the material presentation (the use of illustrations, pictures, colors, and writing that attract students' attention), and the suitability of the illustrations to the material. The display aspect of this textbook received an average score of 3.88. This average score illustrates that the translation of concepts in textbooks has a very valid category.

The average score on this display aspect indicates that the textbook being developed has attractiveness. The attractiveness of textbooks is important, because textbooks that have use value must include several criteria, including being varied, a format that is familiar to students (Schroeder etc, 2009), and contains supporting

pictures of the material presented (Budiningsih etc., 2015). In addition, the illustration of the material presented, in addition to be interesting textbook, it must also be in accordance with the material, because this is the key of attractiveness so that students can understand the material well. Some examples of illustrations in developed textbooks can be seen in Figure 2.

Gambar 11. Perkaratan logam yang memiliki interval waktu yang cukup lama dalam reaksinya. (Sumber: ui-here.com)

Gambar 12. Ledakan bom hidrogen yang dapat dengan cepat terjadi ketika unsur-unsur kimiawi dari bom terse-but dicampurkan. (Sumber: www. amazine.com

Gambar 2 Lapisan ozon adalah salah satu lapisan yang ada di at-mosfer, yang memiliki peran vital dalam keberlangsungan kehidupan di bumi.
(Sumber: zonaozon.blogspot.com)

Figure 2. Examples of Illustrative Images in Textbooks

Student Problem Solving Skills

In this study, in addition to knowing the validity of the textbooks being developed, this study also aims to determine the improvement of students' problem solving skills after implementing STEM-based chemistry textbook-assisted learning. The results of the pretest and posttest students' problem solving skills can be seen in Figure 3.

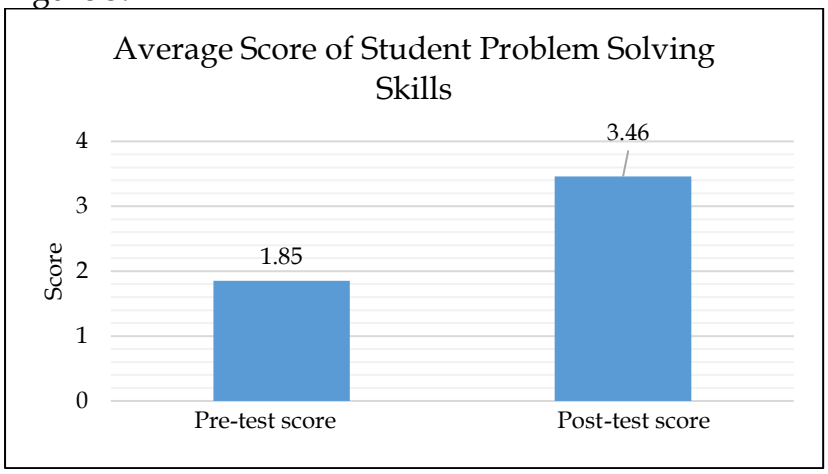


Figure 3. Pretest and Postest Scores of Students' Problem Solving Skills

From the results of the pretest and posttest in Figure 3, the Kolmogorov-Smirnov test for normality is carried out to ensure that the data obtained is normally distributed. The results of the normality test can be seen in Table 6.

Table 6. Data Normality Test for Pretest and Posttest Scores

N		30
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.20276880
Test Statistic		.129
Asymp. Sig. (2-tailed)		.200[c,d]

In the results of the normality test in Table 6, the Asymp.Sig (2-Tailed) significance value is 0.2, so it can be said that the data is normally distributed,

because it has a significance value greater than 0.05. After the data is known to be normally distributed, the data is entered into the n-gain formula to determine the increase in problem solving skills obtained by students. The data on the increase in the score of students' problem solving skills can be seen in Table 7.

Table 7. Data on the Increase in Score of Student Problem Solving Skills

N	Test	Score	n-gain average	Category
30	Pre-test	1.85	0.75	High
	Post-test	3.46		

Table 7 shows that students get a higher score at post test, when compared to scores at pre test. The increase in the score of student problem solving skills shows that STEM-based chemistry textbooks can improve students' problem solving skills as indicated by the n-gain value which gets an average score of increase of 0.75 in the high category. In addition, based on the post test results obtained by students, it shows that the total number of students who completed was 27 students (90%), of a total of 30 total students. The percentage of student completeness is above 75%, which means that the STEM-based chemistry textbooks developed are effective in improving students' problem solving skills. These results are consistent with the opinion expressed by Asunda (2015), which states that textbooks integrated in STEM can train students' problem solving skills.

The increase in the score of problem solving skills obtained is due to the process of getting students used to solving problems in learning through STEM-based textbooks. Temel (2014) states that students who are accustomed to solving problems in the learning process can have positive implications for students' problem solving skills. In addition, research conducted by Aydogdu (2012) shows that in the experimental class students who are taught with problem-based learning have higher results when compared to the control class taught by conventional method.

CONCLUSION

From the research conducted, it can be concluded that 1) the developed textbook has a validity score of 3.70 with a very valid category ; 2) The increase in students' classical problem solving skills was 0.75, with the high category; 3) The percentage of students 'problem solving skills test completeness is 90%, so that STEM-based textbooks can be said to be effective in improving students' problem solving skills.

RECOMMENDATION

This STEM-based Chemistry Textbook is proven to be able to practice students' problem solving skills. In the future, writers hope that STEM-based chemistry textbooks can be developed in other materials in chemistry learning, and are not limited to reaction rate material. In addition, further research is needed on the influence of STEM-based Chemistry Textbooks in practicing other skills, especially skills that are relevant in the 21st century.

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