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The Effectiveness of The STEM Approach on Science Process Skills in Studying Reaction Rate

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Abstract: The students' low science process skills are caused by learning that is still dominated by the teacher, so it is necessary to develop a learning approach that focuses students in the learning process. One approach that can be used is learning that integrates science, technology, engineering, and mathematics (STEM). This study aims to measure the improvement of students' science process skills that are integrated with the STEM approach on the reaction rate material. This research is a quantitative research with a pre-experimental design type, one group pretest-posttest with a sample of 30 students from class XI SMA Negeri 9 Pontianak, taken by random sampling technique. The data collection tool used is a subjective test of science process skills. The results showed that there was an effect of the STEM approach on the students' science process skills on the reaction rate material, with a score of 76.11, good criteria. Among the aspects of science process skills measured, including observation, classifying, calculating, predicting, inferring, and communication, the communication aspect of students experienced a significant increase from a score of 3.33 to 91.1. This study shows that the STEM approach to reaction rate learning effectively improves students' science process skills.

Keywords: Reaction rate, science process skills, stem approach.

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Introduction

Chemistry is a science that studies natural phenomena that focus on the discussion of matter, including the composition, properties, and energy changes that accompany changes in the material (Chang, 2005; Ridwan et al., 2021). Chemistry subjects involve three representations, namely macroscopic, microscopic, and symbolic representations, so that chemistry with abstract concepts is considered difficult for students, especially when implementing it in real life (Sirhan, 2007; Treagust, 2003). In learning chemistry, there are two characteristics of chemistry that need to be considered, namely chemistry as a process and as a result. Chemistry as a product or result in the form of facts, concepts, principles, laws, and theories found by scientists, as well as chemistry is a process that includes skills and attitudes to acquire and develop knowledge (Diara et al., 2017).

The chemistry learning process in schools must emphasize providing direct learning experiences by using process skills and scientific attitudes, integrating learning with real life, not only covering concepts, principles, or theories, but also containing the scientific process so that students understand the nature of science. Chemistry as a process and a product (Bhakti et al., 2020). So, students need to develop Science Process Skills (SPS). Science process skills are one of the skills that need to be possessed in the 21st century (Haryadi & Pujiastuti, 2020).

Science process skills are a series of learning that has an important role. It is necessary to develop innovative learning to improve students' learning science process skills on the material. One approach that can be used is the STEM approach.

SPS stands for Science Process Skills. Science process skills are one of the skills that need to be possessed in the 21st century (Haryadi & Pujiastuti, 2020). Science process skills are a series of learning activities that have an important role in chemistry lessons because they can help students master scientific skills and learn science, develop cognitive abilities,

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construct new discoveries, and apply scientific concepts, principles, and theories in the form of intellectual, physical, and social skills, thereby increasing the optimal use of affective and psychomotor skills (Allamine & Yonata, 2016; Trianto, 2012; Turiman et al., 2012).

The reaction rate is one of the chemistry lessons that includes macroscopic, microscopic, and symbolic aspects, so it is considered difficult for students because it requires the ability to understand, memorize, calculate, and analyze student activities to practice understanding the overall concept (Efliana & Azhar, 2019). Reaction rate learning can take place optimally if students actively participate in learning. Students master material concepts while also developing scientific process skills and attitudes. Currently, reaction rates are generally still taught using conventional methods such as lectures, so that students are less actively involved and tend to memorize theories without mastering science skills and scientific attitudes (Herawati et al., 2013; Sudarsana, 2010) This can make students' science processing skills not develop optimally.

STEM-based learning is an alternative learning that has the potential to be used to build student skills in the 21st century so that students gain knowledge in a more holistic and global way (Sinaga et al., 2021). STEM has been implemented in a number of countries, such as the United States, Japan, Finland, Australia, Singapore, and Indonesia.

STEM which is an initiative of the National Science Foundation in the United States aims to make the four fields in STEM the main career choice for students (Han et al., 2015). According to Strong (2013) the STEM approach is an approach that plays an important role in acquiring and improving students' science process skills. STEM is an understanding that integrates the disciplines of science, technology, engineering and mathematics. STEM education aims to lead students to acquire problem-solving skills by using knowledge and skills in various fields of science simultaneously (Zorlu & Zorlu, 2017).

According to the results of Afifah's research (2021) the STEM approach can improve students' science process skills in learning the material of liquid pressure with an average student score of 92.65. Based on the results of research by (Susanti, 2018), STEM-based learning shows that there is an average difference in the achievement of students' cognitive, affective, and psychomotor competencies of 7.8. The results of research by Rahayu and Sutarno (2021) show that the use of the STEM-based PjBL learning model on the reaction rate material can improve student learning outcomes, namely the score before being given an action is 11.76% and after being given an action it increases to 79.41%. Based on the results of a literature review, STEM learning has been widely researched and proven to improve student learning outcomes, but no one has used the STEM approach to improve science process skills on the reaction rate material. Therefore, in this study, the STEM approach will be applied to improve students' science process skills on the reaction rate material. Based on the description contained in the background, the objectives of this study are as follows: (1) Knowing the effect of the STEM approach on science process skills on the reaction rate material for class XI MIA SMAN 9 Pontianak before and after treatment; (2) Knowing how much the effectiveness of the Pontianak STEM approach on science process skills on the reaction rate material for class XI MIA SMAN 9 Pontianak before and after treatment.

Literature Review

STEM

The term STEM already existed in 1990. At that time, the United States National Science Foundation (NSF) office used the term "SMET" as an abbreviation of "Science, Mathematics, Engineering, and Technology." However, an NSF employee reported that "SMET" sounds almost like "SMUT" when spoken, so it was replaced with STEM (*Science, Technology, Engineering and Mathematics*). This term is used until now (Sanders, 2009). STEM initiated by the United States is an approach that combines the four disciplines in an integrated manner into a problem-based learning method. The method used in STEM is to construct knowledge and skills together.

In addition to the United States, the STEM learning method has been widely used by several developed countries such as the United States, Japan, Finland, Australia, Singapore and several other countries including Indonesia (Permanasari, 2016).

Based on the results of research that has been carried out by Rinto (2019) regarding the application of the *learning cycle model* with the STEM approach to improve the science process skills of Pharmacy Vocational School students on the concept of biotechnology, it was found that the learning cycle model *with* the STEM approach can significantly improve students' science process skills compared to using conventional learning models (Rinto, 2019).

Then the advantages of the STEM approach are that it can shape the character of students because STEM learning guides the mindset of students to solve problems, makes students as inventors, innovators, technology literate, build independence, think critically and logically and can implement the knowledge they get with problems. in his daily life. In addition, the STEM approach can stimulate students to train cognitive, affective, psychomotor aspects, as well as develop, design, utilize technology and apply it in real or everyday life (Rohmah et al., 2019).

Science Process Skills

Science Process Skills are defined as intellectual, physical, and competence abilities that are used as necessary tools for effective science and technology learning such as problem solving, individual development, and social development (Akinbobola & Afolabi, 2010). The Science Process Skills approach can be interpreted as insight or referencing the development of intellectual, social and physical skills that are sourced from the basic abilities that in principle exist in students (Bulkis et al., 2014). According to Piaget, a child's thinking ability will develop if it is communicated clearly and carefully which can be presented in the form of graphs, diagrams, tables, pictures or other sign discussions. Science Process Skills are a combination of various intellectual skills that can be applied to the learning process.

According to Gega (1987), science process skills are also called thinking skills, which are often used by scientists. Thinking skills include aspects: observation, communication, classification, inference, measurement and experimentation. The science process skills are expected to form an understanding of scientific facts and concepts including processes and products, as well as scientific values and attitudes (Markawi, 2015). According to Rahayu and Anggraeni (2017), science process skills are skills that involve cognitive or intellectual, manual, and social skills. Based on some of the opinions above, it can be concluded that science process skills are skills needed by students to understand and master science in the form of cognitive aspects as well as mental, physical and social skills that aim to develop a concept, principle, or theory in the learning process.

Methodology

Research Design

This research is a quantitative research with using the methods of pre-experimental design tipe one group pretest-posttest. The research design is shown in Table 1.

Table 1. One Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O1	X	O2

Information:

O1: Pretest

O2: Posttest

X: Treatment of the experimental class (Sugiyono, 2015).

Sample and Data Collection

This research was conducted at the SMA Negeri 9 Pontianak. The sample collection technique in this study used a purposive sampling technique. Because it is based on several considerations, such as the distribution of the number of students in each lesson session due to the Covid-19 pandemic, the sample in this study was a combination of class XI IPA 1 and XI IPA 4 students who attended the first session, which was a total of 30 students.

Analyzing of Data

The data collection technique used in this study is a measurement technique in the form of scoring in the form of a science process skills test. The instruments in this study used a science process skills test in the form of subjective tests, student worksheet, and lesson plans. The instrument in this study used a science process skills test in the form of subjective tests, worksheets, and lesson plans. The results of the validation of the three validators which each gave a value of 91.66%, 92.85% and 92.5% were then analyzed on average and obtained a validation level of 92.8% with a category suitable for use in research. Then based on the calculation of the data using formula KR.20 obtained a reliability coefficient of 0.56. This shows that the reliability of the test instrument is included in the medium category. Data analysis of the calculation of the percentage of students' science process skills per indicator and for all indicators is shown in equations 1 and 2, as follows:

$$\%SPS = \frac{\text{Score obtained}}{\text{Maximum score}} \times 100 \text{ (Eq. 1)}$$

$$\%Total SPS = \frac{\text{Total SPS Score}}{\text{number of indicators}} \times 100 \text{ (Eq. 2)}$$

The criteria for science process skills in this study are presented in the following Table: (Avianti & Yonata, 2015).

Table 2. Criteria for Science Process Skills

Interval	Criteria
81% < % score 100%	Very good
61% ≤ 80 %	Good
41% ≤ 60 %	Enough
21% ≤ 40 %	Weak
0 % ≤ 20%	Very weak

To find out how much effectiveness the STEM approach has on science process skills on the reaction rate material, Effect Size is used. The Effect Size formula and criteria used are as follows:

$$d = \frac{M_I - M_B}{\sqrt{\frac{SD_B^2 + SD_I^2}{2}}}$$

Findings / Results

Analysis of Students' Science Process Skills

Process skills are skills obtained from training basic intellectual, physical, and social abilities to improve higher abilities (Haryadi & Pujiastuti, 2020). Science process skills applied in teaching and learning activities include the development of cognitive, affective, and psychomotor knowledge. In this study, the aspect of measuring science process skills with the STEM approach on the reaction rate material for class XI high school students is divided into several components, including observation, classification, counting, predicting, concluding, and communication skills.

The following are the results of research using the STEM approach to measure students' science process skills on the reaction rate material by making a project in the form of presenting a video of the tempe-making process. The science process skills of class XI science before and after being taught using the STEM approach experienced an increase in students' science process skills. The change scores for the total pretest and posttest SPS are shown in Figure 1.

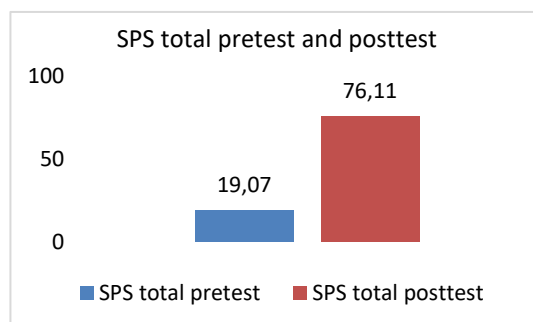


Figure 1. SPS Total Pretest and Posttest Scores for Class XI IPA

Based on the graph above, it shows that there is a change in the average overall score of science process skills for all students in class XI science at the pretest and posttest. From the calculation, the score was pretest 19.07 with very weak criteria and the score was posttest 76.11 with good criteria. At the time of the pretest, the dominant students got scores of 0 and 33.33, but after being given the STEM approach, many students received scores of 66.67 and 100. The average value of the pretest and posttest per indicator can be seen in Table 3.

Table 3. Average of Pretest and Posttest Per Indicator

Aspect	Pretest Average	Standard Deviation	Criteria	Posttest Average	Standard Deviation	Criteria
Observation	32.22	22,28	Weak	81.11	20,86	Very good
Classification	17.77	19,04	Very weak	65.55	25,46	Good
Count	16.66	19,07	Very weak	78.89	16,33	Good
Prediction	17.77	20,95	Very weak	51.11	19,04	Enough
Conclude	26.66	29,55	Weak	88,88	20,21	Very good
Communication	3.33	10,16	Very weak	91.11	14,99	Very good
Average	19.07		Very weak	76.11		Good
Average Standard Deviation	9.07			8,27		

Based on Table 3 above, it shows that the six aspects of the indicator as a whole experienced an increasing change. Of the six aspects, the aspect that experienced a significant increase after treatment using the STEM approach was communication skills, and it concluded with a very good category. This is because in STEM learning, students analyze and solve problems more, so that students can conclude and explain basic communicative concepts in a communicative way material for reaction rate. The application of STEM-based learning emphasizes the student-centered learning process so that students are actively involved in learning, suppress creativity and collaboration, train student skills, construct knowledge, and explore student self-development (Ariyatun & Octavianelis, 2020; Bahrum et al., 2017). While the aspect of predicting students gets enough categories, based on the analysis, this is because there are student failures in interpreting the questions in the test, as seen by the number of students incorrectly predicting the questions on the surface area factor that affects the reaction rate. Based on data processing to test for normality using the paired samples test, the results obtained that the data is normal. The following is a table of the results of pretest and posttest data processing with paired sample *t*-test using SPSS 25.0.

Table 4. The Results of Pretest and Posttest Data Processing

		Paired Samples Test				
		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	
Pair 1	Pretest-posttest	-57.03633	9.56007	1.74542	-60.60612	
		Paired Samples Test				
		Paired Differences 95% Confidence Interval of the Difference Upper				
				t	df	Sig. (2-tailed)
Pair 1	Pretest-posttest			-32.678	29	.000

Based on the calculation of the pretest and posttest data of the sample pairs *t*-Test test with the help of SPSS 25.0, it is known that the value of sig. (2-tailed) of $0.000 < 0.05$, it can be concluded that there is a significant difference between students' science process skills in the pretest and posttest data, which means that there is an effect of using the STEM approach on the science process skills of class XI IPA students at SMAN 9 Pontianak. Then to find out the effectiveness of the STEM approach on science process skills on the reaction rate material seen from the effect size value. Based on the calculation, the effect size value is $6.57 > 1.00$, it can be concluded that the use of the STEM Approach to science process skills on the reaction rate material for class XI IPA at SMAN 9 Pontianak has a strong effect, meaning that STEM is very effective in improving skills students' science process on the material of the reaction rate of class XI IPA SMAN 9 Pontianak.

Discussion

The STEM Learning Process in the Classroom

This study aims to determine the effectiveness of the STEM approach on science process skills on the reaction rate material. The material for reaction rates is delivered in class XI in odd semesters. Learning in the experimental class material reaction rate is as much as 2 meetings. The first meeting consists of initial activities, core activities, and final activities. The initial activity was in the form of giving a pre-test and providing material and discussion using the STEM approach. In the core activity, students formed groups and discussed the application of aspects of science, engineering, and mathematics to the reaction rate material, after which students were assigned to present a video of making tempeh in the second meeting. Then for the second meeting, the learning steps are the same as for the first meeting. At the second meeting, the learning activities applied aspects of technology by way of students' explaining videos on the use of catalysts in making tempeh. After that, the teacher gave a conclusion from the reaction rate learning and continued with the post-test. The following aspects of STEM are applied to classroom learning:

Science

The application of the scientific aspect to the reaction rate Learning is carried out by providing case studies in the student worksheet, then students in groups understand, discuss, and analyze the phenomena contained in the case studies by utilizing various sources and scientific literacy. Scientific literacy is the ability of students to analyze scientific information and apply it to everyday life to obtain solutions to problems. In this aspect, after students have finished discussing, they are asked to explain the results of problem solving from the case study. In this aspect, students analyze problems related to the concept of reaction rate, such as collision theory, and the factors that affect reaction rates in everyday applications. Thus, students can build their own knowledge and solutions to the problems that they find.

Engineering

In this aspect, engineering is related to the ability of students to develop their creativity and technological innovation through combining several fields of knowledge. In this study, students in groups designed a procedure or test for a simple practicum tool in the factors that affect the reaction rate. In this study, a simple practical tool that they designed is the concentration factor that affects the reaction rate using baking soda, vinegar, bottles and balloons. On bottle A, one spoon of baking soda was added, and on bottle B, two spoons of baking soda were added, each containing 20 ml, and then they were measured using a stopwatch, the rate of the balloon. After they design and conduct the experiment, they explain what happens to the factors that affect the rate of the reaction. This experiment trains students to predict and think critically when analyzing information from experiments so that they know that the amount or concentration is very influential in the reaction rate; the higher the concentration, the faster the reaction rate.

Technology

In the technological aspect, the implementation of technology in reaction rate learning is done by presenting videos of making tempeh on one of the social media collaboratively by students. From this aspect, students become aware of the technique of making tempeh and its relation to the addition of catalysts in everyday life to the reaction rate. Besides that, it trains students in accessing the internet and using a stopwatch as a basis for comparing reaction rates. The results of making tempe can be seen in Figures 2 and 3.



Figure 2. The Process of Making Tempe With Yeast.



Figure 3. The Process of Making Tempe Without Yeast.

This aspect trains students' skills in collaborating and seeking information. In making tempe by students, there were some that did not work or the process of changing soybeans into tempeh took a long time due to errors in the use of yeast. Some groups use baker's yeast and some do not use yeast. This is what makes tempeh a failure. Then many of the groups succeeded by using a special yeast for tempe and the manufacturing process was appropriate so that the conversion of soybeans into tempeh only took 2 days. From this, students become aware that the role of yeast in making tempeh is very important, yeast is have an important role as a catalyst to accelerate the reaction rate, so that without yeast or catalysts, the reaction rate will take a long time to take place.

Mathematic

In the mathematical aspect, students are given a brief explanation of the concept of reaction rate and reaction order, and then students are given case study questions related to the calculation of reaction rates and reaction orders in the student worksheet. This element assesses students' capacity to analyze, interpret, and communicate their thoughts, as well as their ability to apply mathematical concepts. Students can create their idea of the level of students' understanding from this learning exercise, particularly when it comes to concepts and data processing.

According to the STEM approach to Science Process Skills, the reaction rate to research material has grown, because students are not just instructed about the proper concept during learning. They were, however, directed to independently discover the concept through a simple experiment on the factors affecting the rate of a response. Additionally, students' science process abilities are enhanced through a series of exercises associated with the student worksheet and analytical

strategies that aid students in comprehending the true notion. Additionally, students are assigned the job of creating a film project on tempeh manufacturing, which helps them practice several areas of their science process abilities. It seeks to assist students in comprehending science principles that are utilized in STEM, so that they can participate actively and create their own learning experiences (Bhakti et al., 2020). In accordance with constructivism's principles of learning, which emphasizes the process of actually experiencing learning activities in order for students to discover learning concepts and their own knowledge of learning (Rusilowati et al., 2016).

According to Apaivatin et al., (2021) the STEM approach to learning activities is capable of enhancing students' science process skills, not just their abilities, but also of facilitating science learning, increasing student activity, and increasing students' responsibility and confidence in learning. Thus, the STEM method has a considerable impact on students' science process skills.

Conclusion

The conclusion obtained is that the STEM approach affects the science process skills of class XI IPA SMAN 9 Pontianak on the reaction rate material. This is indicated by the results of the calculation of the science process skills of class XI IPA after the treatment obtained a score of 76.11 in the very good category and an effect size value of 6.57 was obtained in the Strong Effect category.

Recommendations

Based on the results of the research that has been done, the researchers provide suggestions as follows: It is better if the teacher can consider the STEM approach (science, technology, engineering, and mathematics). Approach STEM is applied learning that uses interdisciplinary approach (science, technology, engineering, and mathematics) apply and practice the basic content of STEM on the conditions that students find in their lives. As an insight so that it can be used in schools. Another suggestion is educators should be able to concentrate learning activities by develop critical thinking skills and scientific attitude maximum for students. In addition, this study needs further research to increase its effectiveness. Therefore, it is expected that future researchers can conduct further research on other materials using the STEM approach in other subjects at school and it is recommended that the method used is developed.

Limitations

This study has limitations that reduce the generalizability of the findings, namely: first, it is not representative which is relatively small sample size. Second and most importantly, it must be recognized that there are various factors that can contribute to the results of research on the measurement of science process skills.

Authorship Contribution Statement

Rahmawati: Conceptualization, design, analysis, writing. Fadhilah: Editing, supervision, final approval.

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