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Implementation of STEM-Integrated PjBL Based on Lesson Study: Improving Students' Critical Thinking Skills

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Abstract

This study aims to examine the application of lesson study design on chemistry material in improving critical thinking skills of students in class XI-2 SMA Negeri 2 Semarang. The research was conducted for three meetings involving the implementation of Project-Based Learning (PjBL) learning model with STEM (Science, Technology, Engineering, Mathematics) approach. The lesson study stages included planning, implementation, and reflection focusing on reaction rate material, involving students in collaborative activities such as designing and testing simple tools. The results showed that the application of the STEM-based PjBL model significantly improved students' critical thinking skills. This improvement can be seen from students' ability to identify, analyse, and solve problems based on relevant theories. The learning activities implemented, such as group discussions and windows shopping activities, also play an important role in improving interaction and collaboration between students. The implementation of STEM in PjBL not only deepens students‘ understanding of chemical concepts, but also increases students’ interest and active participation in the learning process. This study concludes that the application of STEM-based PjBL learning model, collaborated with lesson study, is able to improve critical thinking skills and the quality of chemistry learning on reaction rate material.

Keywords: critical thinking; lesson study; project based learning; STEM

Abstrak

Penelitian ini bertujuan untuk mengkaji penerapan desain lesson study pada materi kimia dalam meningkatkan keterampilan berpikir kritis siswa kelas XI-2 SMA Negeri 2 Semarang. Penelitian dilaksanakan selama tiga pertemuan yang melibatkan penerapan model pembelajaran Project-Based Learning (PjBL) dengan pendekatan STEM (Science, Technology, Engineering, Mathematics). Tahapan lesson study mencakup perencanaan, pelaksanaan, dan refleksi yang berfokus pada materi laju reaksi, melibatkan siswa dalam aktivitas kolaboratif seperti perancangan dan uji coba alat sederhana. Hasil penelitian menunjukkan bahwa penerapan model PjBL berbasis STEM secara signifikan meningkatkan keterampilan berpikir kritis siswa. Peningkatan ini terlihat dari kemampuan siswa dalam mengidentifikasi, menganalisis, dan menyelesaikan permasalahan berdasarkan teori yang relevan. Aktivitas pembelajaran yang dilaksanakan, seperti diskusi kelompok dan kegiatan windows shopping, juga berperan penting dalam meningkatkan interaksi dan kolaborasi antar siswa. Implementasi

STEM dalam PjBL tidak hanya memperdalam pemahaman siswa terhadap konsep kimia, tetapi juga meningkatkan minat dan partisipasi aktif siswa dalam proses pembelajaran. Penelitian ini menyimpulkan bahwa penerapan model pembelajaran PjBL berbasis STEM, yang dikolaborasikan dengan lesson study, mampu meningkatkan keterampilan berpikir kritis dan kualitas pembelajaran kimia pada materi laju reaksi.

Keywords: berpikir kritis; lembar kerja; project based learning; STEM

Introduction

Education is a means of acquiring the skills necessary for an individual to compete in the global era. It serves as a tool to develop abilities and shape the behavior and personality of students, making them believers with noble morals, skilled, and reasonable. Likewise, the educational process in schools aims to shape attitudes, develop intellectual intelligence, and enhance students' skills according to their needs.

Islam places significant emphasis on 21st century learning demands the application of methods that are able to develop various essential skills, such as critical thinking, problem solving, collaboration, and creativity. Critical thinking skills are one of the abilities that must be mastered by students to be able to face increasingly complex global challenges. One learning model that is considered capable of fulfilling this need is Project-Based Learning (PjBL) which is integrated with the STEM (Science, Technology, Engineering, and Mathematics) approach.

Chemistry learning in secondary schools is often still dominated by traditional learning methods that do not provide space for students to think critically and creatively (Nasir Ahmad et al., 2020). This is exacerbated by the abstract nature of chemistry material, which often makes students passive in the learning process. The 2022 PISA (Programme for International Student Assessment) survey announced in December 2023 showed a decline in Indonesian students' science literacy scores, indicating low critical thinking skills and the ability to understand scientific concepts (PISA, 2022). According to Sani et al. (2022), the learning model applied in the classroom is one of the main factors that hinder the development of students' critical thinking skills.

The Project-Based Learning (PjBL) learning model with a STEM approach is considered as one of the solutions to improve students' critical thinking skills in science learning, especially chemistry. PjBL provides opportunities for students to actively participate in the learning process, solve real problems, and produce meaningful products, thus stimulating critical and collaborative thinking skills (Wahyudi, 2021). In addition, the STEM approach offers an integration of four disciplines (science, technology, engineering, and mathematics) that requires students to think critically, creatively, and collaboratively in solving real problem-based projects (Winaryati Eny, 2023).

The theory of constructivism proposed by Vygotsky emphasises that students construct knowledge through social interaction and direct experience. PjBL learning integrated with STEM is in line with this theory, as students are involved in active and collaborative inquiry to solve problems related to the real world (Kristiani, n.d.). This is in line with Piaget's view that effective learning is learning that involves higher cognitive activities, such as critical thinking, analysis and evaluation.

The STEM and PjBL approaches also support the development of 4C skills (Creativity, Critical Thinking, Communication, and Collaboration) that are indispensable in 21st century learning (Ariyatun & Octavianelis, 2020). Students are not only encouraged to master concepts, but are also expected to be able to connect their knowledge with the real world, so that their critical thinking skills can be honed.

Project-based learning involving the STEM approach also prepares students to face the challenges of the globalisation era

which requires them to master scientific and critical thinking skills in dealing with complex problems (Widana & Septiari, 2021). Therefore, the application of the STEM-integrated PjBL model is important in an effort to improve students' critical thinking skills, especially in chemistry learning.

Several previous studies have shown the effectiveness of the PjBL model and the STEM approach in improving learning outcomes and critical thinking skills. Research by Wahyudi (2021) revealed that the application of PjBL significantly encouraged students to come up with creative ideas and critical solutions in chemistry learning. The study found that through problem-based projects, students are more encouraged to think critically in exploring chemical concepts that are often abstract. This finding is also corroborated by Suriti's study, (2021), which showed a significant increase in students' critical thinking skills on chemical equilibrium material after the implementation of STEM-based learning.

In addition, Ariyatun & Octavianelis' research (2020) concluded that the integration of Problem-Based Learning (PBL) with a STEM approach has a significant effect on improving students' critical thinking skills. This finding reinforces the idea that the integration of problem-based learning and STEM can create a learning environment that encourages students to think analytically, logically, and critically. The study also emphasised that the implementation of STEM-integrated PjBL model can be more optimal if it is implemented collaboratively through Lesson Study.

Lesson Study is a collaborative approach that involves teachers in planning, implementing and evaluating learning systematically. Lesson Study is proven to improve the quality of learning, especially in developing students' critical thinking skills. Winaryati et al (2023) found that the implementation of Lesson Study in STEM learning has a significant impact on improving students' critical thinking skills in chemical reaction materials. The study concluded that the implementation of Lesson Study creates a reflective learning environment, where teachers can evaluate and improve learning strategies continuously.

These studies provide a strong empirical foundation for the research to be carried out with the title 'Application of PjBL Integrated STEM Based Lesson Study: Improving Students' Critical Thinking Skills'. This study aims to examine the effectiveness of the application of the PjBL model integrated with the STEM approach through Lesson Study in improving students' critical thinking skills, especially in chemical reaction rate material. Thus, this research is expected to contribute to the development of a more effective learning model in supporting students' critical thinking skills, which is one of the main demands of 21st century education.

Method

This research has a main focus on the evaluation of model teachers, observer teachers and students on the implementation of chemistry learning that has been designed and implemented (Fadloli, 2014). Data were gathered in the form of activity transcripts, interviews, field notes, videos, photographs, and documents of learning activities as qualitative data that will be analysed (Abdussamad, 2021). his qualitative data is used as an effort to build individual understanding and experience related to the information and meaning of Lesson Study activities. This activity produces information building so that it is able to present a representation of complex information experiences. The approach method used is to explore the information obtained from each stage by the Lesson Study team. This research was conducted in January-March 2024 with the research subjects were students of class XI-2 of State Senior High School in Semarang city, the material of reaction rate (Winaryati et al., 2024).

Observers in this study are: chemistry teachers, lecturers, peers, lecturers from Malaysia who are experts in

STEM and Lesson study, namely from UKM (Universiti Kebangsaan Malaysia) and UM (University Of Malaya). Observations were conducted to obtain information about the actual actions of the observers. The assessment of students' critical thinking skills directly used an observation sheet containing dimensions and indicators of critical thinking (Mania, 2008). Interview activities were conducted by researchers to 1 chemistry teacher and 3 student representatives from the class that has been implemented lesson study activities. Observation by Malaysian lecturers was conducted online by observing the lesson that had been implemented through video. Researchers used an interview guide or called a semistructured interview. Documentation conducted by researchers is in the form of videos and photos during learning in the form of student activities following learning, classroom conditions and others that support the collection of field research data.

The research instrument is the researcher himself who plays a role in carrying out planning, collecting data, analysing data, and making conclusions that must be done carefully. Other instruments include teaching modules, LKPD, interview guidelines, validation sheets and observation sheets. The research variables and dimensions used in this study are the dimensions and indicators of critical thinking skills based on the results of research (Eny Winaryati, 2023) which have been validated as follows the Table 1.

Table 1
Dimensions and Indicators of Critical Thinking

Dimension	Indicator
Dimension 1. Information Literacy Skills	Able to identify information appropriately; Analyze the selected information; Seeking the truth of information.
Dimension 2. Critically Reasoning Findings	Having high curiosity; Able to collect the information needed; Able to draw conclusions based on empirical evidence.
Dimension 3. Critical Activity	Critical in argumentation; Integrate things correctly.

(Eny Winaryati, 2023)

The data collection process in this study was carried out following the lesson study flow including:

1. Plan Stage

At this stage, the stage of designing learning activities carried out by the researcher as a model teacher together with the lesson study team about learning tools in the form of teaching modules and LKPD which will later be applied in class learning. Instrument making and instrument validity testing were also carried out at this stage.

2. Stage Do

At this stage, researchers collected data in the field in the form of learning outcomes, interviews, observations and documentation. From these results, researchers are able to find out the data collected so that researchers are able to present data in accordance with the research objectives.

3. See Stage

At this stage, the model teacher together with the lesson study team discussed and observed the results of classroom observations related to how students learn and look for students' weak points. The result of this activity is as an evaluation material to find the right method and can be used in the next meeting. This aims to improve learning and mastery of material in students.

Result and Discussion

This research was intended to determine the application of lesson study design to chemistry subject matter to

improve students' critical thinking skills in class XI-2 SMA Negeri 2 Semarang. The research was conducted for 3 meetings or 7 learning hours with the following details the Table 2.

Table 2
Research Implementation

Implementation Date	Total Learning Hours
20 Februari 2024	2 hours (90 minutes)
22 Februari 2024	3 hours (135 minutes)
27 Februari 2024	2 hours (90 minutes)

The following are the stages of lesson study that have been carried out by researchers:
a. Planning Stage (Plan)

The results of the plan activity are Chapter design and lesson design can be seen in Figures 1 and Figure 2. Chapter design contains an explanation of the material that will be used in this lesson, namely reaction rate material with collision theory sub-materials and factors that affect the reaction rate. Lesson design model teachers also explain that the learning that will be carried out uses a collaboration of PJBL learning models with a STEM approach.

Figure 1
Chapter Design

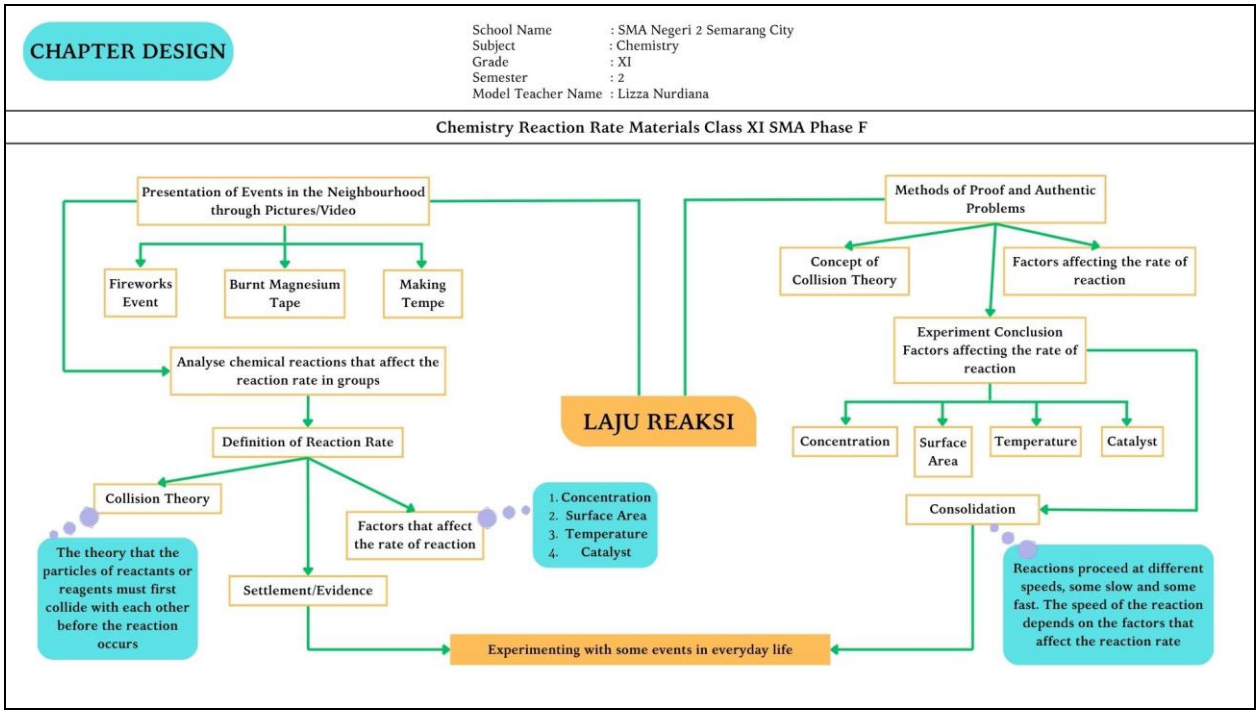
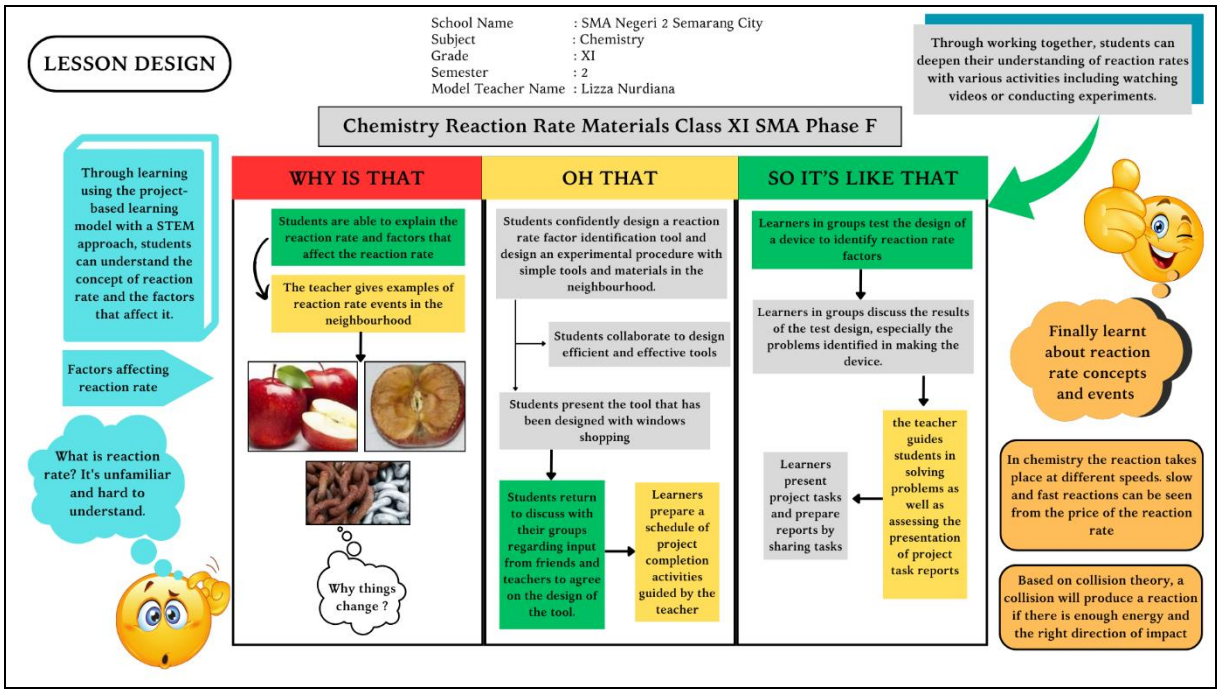


Figure 2
Lesson Design



PjBL learning implemented using the STEM approach (Science, Technology, Engineering, Mathematics) which can be analysed for its application in STEM PjBL learning on Reaction Rate material in class XI-2 as follows:

- Science
  Students will learn about the events of collision theory, factors that affect the reaction rate, and analyze the concept of reaction rate in the environment around students.
- Technology
  The use of simple tool technology that has been made from the results of student projects to identify reaction rate factors, the use of a stopwatch to determine the time a material reacts, the use of learning applications such as learning videos as learning references and quizizzes as learning evaluation technology.
- Engineering
  Students design tools to identify reaction rate factors, design experimental procedures using tools that have been designed and test the design results.
- Mathematics
  Students calculate changes in time from experimental data and create tables and graphs of the effect of concentration, temperature, surface area on time.

b. Implementation Stage (*do*)

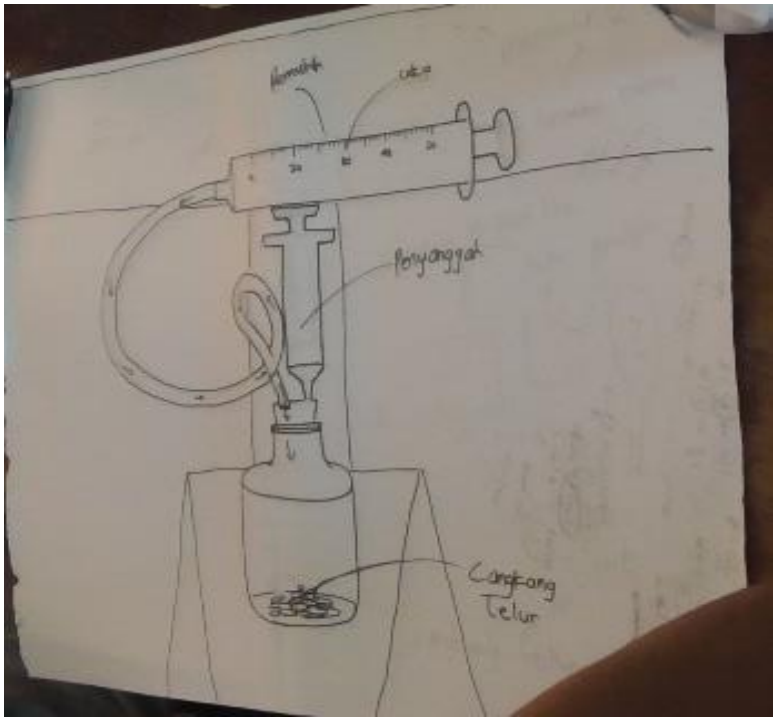
In this meeting the model teacher conducted the reflection phase of the PjBL learning model. The model teacher provides videos or pictures related to chemical reactions around students then asks "do students already know why these reactions occur?". This aims to bring students into the context of the problem and inspire students to immediately start investigating. This phase is also intended to connect what is known and what needs to be learnt. The observation results show that students are able to identify information appropriately through video and picture presentation.

The next stage in the PjBL learning process is the research stage. This stage is a form of student research that will make students contribute more in the learning process. At this stage the model teacher divides students into several discussion

groups to assign students "How to design a set of tools using simple tools and materials around to identify factors that affect the reaction rate". In this phase, the flow of STEM activities that will be implemented begins to appear, namely the "Ask" activity carried out by the model teacher by asking the question to students. The model teacher provides examples of tools that can be used by students and provides several references that can be used as reading materials to collect relevant information. During the research phase, teachers more often guide discussions to determine whether students have developed conceptual and relevant understanding based on the project.

Observations and documentation show that students are quite active in group discussions with very creative ideas and there are some groups that use some materials that are rarely used in simple experiments. The activity of finding sources of information, designing and producing designs is called the "**imagine**" activity in the STEM learning process. The results of the design that they have designed in the form of drawings on manila paper and decorated as creatively as possible are shown in the picture below in Figure 3.

Figure 3
Reaction Rate Identification Tool Design Results



The results of the designs that have been designed by students are presented through windows shopping activities carried out by means of design designs affixed to the wall, there is a presenter of each group and group members go around observing the designs of other groups and providing feedback in turn (feedback on designs from other groups is written on manila paper containing tool designs). This activity will train them to improve their critical thinking skills. The windows shopping activity also trains them to accept and be open to various suggestions from other groups. Students can also think rationally about the designs they see from other groups.

The lesson ended with students conveying the conclusions obtained, and the modelling teacher gave students the opportunity to agree on the design that would be tested at the next meeting. An agreement will also be made to determine the schedule for completing the tool and conducting the tool trial. The agreement that

has occurred between the modelling teacher and students will end the "plan" stage in the discovery phase of the PJBL STEM learning flow. The activity will continue with the "creat" stage which will be carried out by students through the process of making tools that have been designed at school under the guidance of the teacher.

Figure 4
Implementation of Tool Testing

The Figure 7 above is the implementation of the tool trial as the application stage in the flow of the implementation of the PJBL learning model. The implementation of this tool trial was carried out by students in accordance with the procedures they made. Each group is very enthusiastic about what happens with their respective tools. When there is a failure or discrepancy with the initial design, they try to find out and correct their mistakes. From the events that occurred, they tried to relate to the theory they had obtained in the previous meeting so that students' enthusiasm increased.

Each group conveys the results of their tool testing to friends and teachers, this activity is the communication stage in the PJBL learning process. In this case, students were able to explain the relationship of the lab work they did with the material of collision theory and also the factors that affect the reaction rate. Students also conveyed the failures they had experienced before and how they overcame these failures.

c. Reflection Stage (see)

Overall, the 3 observers stated that students' thinking skills could be seen through the PJBL-STEM learning process. This can be seen from students' activities in finding information through existing literature to design the design of rate identification tools, the implementation of windows shopping activities that are able to make students actively ask other groups related to the different designs of each group. the implementation of learning that has been done is also able to make students convey the conclusions obtained from the observations of the experiments that have been carried out. Suggestions given by the observers for further learning are related to the deepening of material on the surface area factor and the use of PPE and work safety appeals in the laboratory.

Based on the data obtained from observations made by observers and the results of interviews with students and teachers, it can be analysed based on indicators of critical thinking skills summarised in 3 dimensions of critical thinking skills, namely: information literacy skills, reasoning findings critically and carrying out critical activities. The overall results of the analysis of critical thinking skills described by researchers are the opinions of the observers and researchers themselves. The critical thinking skills described are also the general abilities possessed by the group and not observed by individual students.

1. Information Literacy Skills

Based on the results of the analysis of students' critical thinking skills with 3 indicators in the dimensions of information literacy skills, it shows that students are able to identify, analyse and seek the truth of information. The whole group was able to design tools and procedures to be carried out based on supporting theories obtained from the internet, articles and books. Critical thinking skills can be seen by observers during open class through the PjBL learning model with a STEM approach where students play a more active role during the learning process so as to increase their confidence in understanding something new based on the results of the information literacy they have performed. Research of (Rizky et al., 2020) also explained that the PjBL STEM learning model was able to increase the learning activeness of students in class XI MIPA 5 SMA Negeri 2 Jember Kabupaten Jember on elasticity material.

This is also supported by the results of students' summative tests which show that 33 students are able to solve the problems given by the teacher well, meaning that in this case students are able to capture the information they get independently well and the concept errors they experience are quite small. This is in line with several previous studies that used the PjBL model with a STEM approach including the results of research (Aureola Dywan et al., 2020) (Widana & Septiari, 2021) (Allanta & Puspita, 2021) which resulted in improved student learning outcomes in mathematics and science materials.

2. Analyzing Findings Critically

Based on the results of interviews with students, the discussion activities carried out and the activities of designing tools can motivate students to learn chemistry seriously, meaning that indirectly the students' interest in learning chemistry has increased. The PjBL learning model based on the STEM approach can affect the learning environment of students, where the classroom situation becomes more conducive, the learning atmosphere becomes fun, even collaboration between students can also trigger a learning atmosphere that is missed by students to learn together. This is also in line with the research of Rizky et al. (2020) that students are more enthusiastic in learning activities with the PjBL STEM model than the conventional learning model where students listen more to the teacher's explanation.

The process of implementing the tool trial that has been carried out shows that there are various problems encountered by students but can be resolved well with mutual cooperation based on the results of exposure by students. The observers also said that during the tool trial, students focused on paying attention to the phenomena that arose during the experiment. Students try to find out the mistakes in the experiments carried out if problems are encountered in their implementation. This means that in this case students are able to critically reason their findings by making improvements to the tools they have tested. This is in accordance with the research of Allanta & Puspita (2021); Aureola Dywan et al. (2020) which states that the use of the STEM-based PjBL learning model is more effective in improving students' critical thinking skills.

3. Carrying out Critical Activities

Through the PjBL learning model with a STEM approach, learners more often interact or have discussions with peers than with teachers. This is what provides a stimulus to learners in maintaining critical activities through a continuous discussion process. The results of interviews conducted with students also show that students feel happy with the discussion activities carried out because they can exchange information with each other. This is in line with the research of Aureola Dywan et al. (2020) Aureola Dywan et al. (2020) that the results showed that the discussion process carried out in groups had a better influence in improving critical thinking skills. This happens because students are encouraged to have many discussions so that they can find

new information according to the answers needed.

The technological aspect of STEM learning, namely the tools they use in identifying reaction rates, is also a special attraction that can increase students' enthusiasm for learning to solve contextual problems. The submission of the observers also showed that the learning activities carried out during the three meetings showed a continuous critical activity. This is shown from the initial discussion process of determining the design of the tool, the discussion process with the teacher, the discussion process with other groups (suggestions / input from the results of windows shopping activities), the process of assembling the tool, the process of testing the tool, the process of repairing the tool and the process of presenting the test results.

4. Improving Learning Quality through Lesson Study

Through lesson study, any shortcomings of the teaching teacher in learning will be reduced by the presence of peers as observers. The presence of observers will provide suggestions for the improvement of the next learning implementation, so that the teacher's ability in classroom management becomes better. The implementation of lesson study in this study was able to have a good impact on students, such as more courage to express opinions, enjoy learning and improve cooperation between students. This is in line with research (Sani et al., 2022) that the application of collaborative learning based on lesson study can effectively improve the quality of learning and active participation of students. The existence of lesson study activities can also improve teacher performance and competence in terms of planning and preparation of learning tools, learning implementation process, and learning evaluation process.

The implementation of lesson study in this study was able to have a good impact on students, such as more courage to express opinions, enjoy learning and improve cooperation between students. This is in line with the research of Sani et al. (2022) that the application of collaborative learning based on lesson study can effectively improve the quality of learning and active participation of students. The implementation of lesson study activities can also improve the performance and competence of teachers in terms of planning and preparation of learning tools, the process of implementing learning, and the process of evaluating learning.

Conclusion

According to the results of the study, it can be concluded that the application of PjBL learning based on the STEM approach is able to improve students' critical thinking skills in the chemistry of reaction rate in class XI-2 SMA Negeri in Semarang. The STEM approach is able to make students better understand the concept of reaction rate by being directly involved in project preparation, tool design, and problem solving using chemical concepts. The implementation of lesson study in the implementation of this research also contributed suggestions for improving the implementation of further learning. In addition to the learning models and approaches used, there are several things that also affect students' critical thinking skills in the classroom. The ability of each student is the most important factor in influencing the improvement of critical thinking skills, using any learning model if students have more ability then learning will be accepted easily and does not require too much effort. Based on the results of researcher observations before and after PjBL STEM learning, it was found that the influence of classroom situations was also a supporting factor in improving critical thinking skills, seating made in groups had a better influence, because group seating encouraged students to have many discussions so that students could find new information according to the answers needed.

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