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EVALUATION OF THE EFFECTIVENESS OF MATHEMATICS AND NATURAL SCIENCES LEARNING AT SMA NEGERI 5 KARAWANG THROUGH A SCIENTIFIC APPROACH

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Abstract

This study evaluates the effectiveness of implementing a scientific approach in mathematics and natural science learning at SMA Negeri 5 Karawang, focusing on its influence on student learning outcomes, learning activities, and teacher competence. Using a mixed-method design with a pretest–posttest model and descriptive observations, the research involved 90 students of class XI MIPA and 6 MIPA teachers. Data were collected through learning outcome tests, student activity observation sheets, and teacher competency evaluations, and analysed using descriptive statistics and gain scores. The findings show that the scientific approach significantly enhances student learning outcomes, with the average pretest score of 70.15 increasing to 82.01 on the posttest, representing a 16.9% improvement and an N-Gain score of 0.47 in the moderate category; the greatest progress was observed in reasoning skills (C4) and the application of concepts (C3), indicating strengthened critical and analytical thinking. Student learning activities also improved at each stage of the scientific process: observation increased from 70% to 88%, questioning from 61% to 84%, experimenting from 65% to 86%, reasoning from 63% to 85%, and communicating from 67% to 86%, resulting in an overall increase of 20.6% in the high category and reflecting more active, creative, and collaborative engagement. From the teacher's perspective, competence in implementing the

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scientific approach reached an average score of 3.3 in the good category, with the highest score in lesson planning (3.7) and the lowest in guiding scientific communication (2.9), suggesting the need for further professional development in facilitating student reporting and presentation of experimental findings. Overall, the study concludes that the scientific approach is effective in improving student learning outcomes and classroom activities while supporting teacher competence, and it provides empirical evidence to inform efforts to strengthen teaching practices and targeted capacity-building in scientific communication.

Keywords: Scientific Approach; Mathematics Learning; Natural Science Learning; Student Learning Outcomes; Teacher Competence; SMA Negeri 5 Karawang

INTRODUCTION

Mathematics and Natural Sciences (MIPA) learning at the Senior High School (SMA) level has a strategic role in shaping students' critical, creative, and scientific thinking skills as a provision to face the challenges of the 21st century. Through subjects such as Physics, Chemistry, Biology, and Mathematics, students are directed to understand natural phenomena systematically and based on empirical evidence (Trianto, 2018). However, in practice, MIPA learning in many schools is still dominated by conventional approaches that focus on delivering material and practice questions, rather than on the actual scientific discovery process (D. Astuti, 2020).

The results of observations conducted by researchers in September 2025 at SMA Negeri 5 Karawang show that the implementation of the scientific approach as mandated in the 2013 Curriculum has not been running optimally. Based on observations of three MIPA classes (XI MIPA 1, XI MIPA 2, and XI MIPA 3) as well as interviews with subject teachers, it is known that learning activities still tend to be *teacher-centered*. Teachers explain formulas, concepts, and theories more directly, while students just listen and take notes. Scientific stages such as *questioning* and *reasoning* are often neglected, and *experimental* activities are rarely carried out due to limited time and laboratory facilities (R. W. Astuti, 2020).

The results of the initial questionnaire of 120 students showed that 61% of students found the lessons of mathematics and mathematics difficult to understand, and 54% stated that learning activities were less interesting because there were too many theories and practice problems. Students also revealed that experimental activities were only carried out before the practicum exam, not as a routine part of the learning process. This shows that the essence of

the scientific approach, which should emphasize scientific thinking processes and hands-on learning experiences, has not been fully implemented in the field. This condition is in line with the findings of (Muslichah, 2021) who stated that limited time and learning facilities are the main obstacles to the implementation of scientific approaches in secondary schools.

From the teacher's side, most of them admitted to understanding the concept of the scientific approach, but were not able to implement it consistently. Teachers still have difficulty managing time to carry out the five scientific stages in their entirety: observing, questioning, trying, reasoning, and communicating. Some teachers also mentioned that the administrative burden and demands for completing the syllabus made them prefer the lecture method so that the material could be completed on time. This condition is supported by research by (Putri & Rachmawati, 2023) which shows that the success of scientific approaches is greatly influenced by teachers' readiness to design flexible and contextual learning scenarios (Audina Pratiwi et al., 2023).

In addition to the teacher factor, the learning infrastructure at SMA Negeri 5 Karawang has also not fully supported experimental activities. Based on the results of the documentation, the MIPA laboratory only has basic equipment and is not equipped with modern practicum tools such as digital microscopes, data sensors, or advanced chemical test equipment. As a result, experimental activities are often carried out demonstratively by teachers, not exploratory by students. In fact, according to (Sani, 2019) and recent research by (Audina Pratiwi et al., 2023), the success of the scientific approach is highly dependent on the active involvement of students in observing and deducing phenomena directly.

This phenomenon has an impact on the low activity and scientific thinking ability of students. Based on the analysis of odd semester test scores for the 2024/2025 school year, the average MIPA score in class XI only reached 72.3, with a minimum completeness standard (KKM) of 75. Aspects of science process skills, such as the ability to interpret data and compile reports on the results of experiments, are also relatively low. These results are in line with the findings of research by (Nursaadah et al., 2025) which identified the weak scientific skills of high school students due to the lack of experimental experience and reasoning activities during learning.

As explained by (Hosnan, 2014), the scientific approach is not just a procedural step, but is a learning model that emphasizes the discovery of concepts independently through a structured scientific process. When this approach is applied optimally, students not only

understand the material, but also develop critical, collaborative, and communicative thinking skills ((Yuliani & Handayani, 2023). Therefore, an evaluation of the effectiveness of the application of scientific approaches in learning mathematics and mathematics at the high school level is very important to measure the extent to which this approach is able to improve learning outcomes and the quality of the learning process.

Based on this background, this study was conducted with the aim of evaluating the effectiveness of MIPA learning through the application of a scientific approach at SMA Negeri 5 Karawang. The main focus of this study includes: (1) improving student learning outcomes after the application of scientific approaches, (2) changes in student learning activities during the learning process, and (3) teachers' competence in managing scientific-based learning. The results of this study are expected to provide an empirical picture of the implementation of scientific approaches at the high school level and become a reference for the development of more contextual and effective MIPA learning strategies in the 21st century education era.

METHODS

This study uses a mixed methods approach with a sequential explanatory design, which is an approach that begins with the collection and analysis of quantitative data, then continues with the collection and analysis of qualitative data to deepen and explain the results of the initial findings more comprehensively. This approach was chosen because the effectiveness of MIPA learning through a scientific approach can not only be seen from the quantitative improvement of student learning outcomes, but also needs to be understood from the perspective of the process, experience, and perception of teachers and students qualitatively. This research was carried out at SMA Negeri 5 Karawang, which is located on Jalan Kertabumi, Karawang Regency, West Java. This school was chosen because it has implemented the Independent Curriculum which encourages the application of scientific approaches in learning and mathematics and mathematics, as well as having relatively complete laboratory facilities and teachers who actively participate in learning innovation training. The research subjects consisted of 90 students in grade XI of the MIPA program which were divided into three classes, namely XI MIPA 1, XI MIPA 2, and XI MIPA 3, as well as six teachers of MIPA subjects which included Physics, Chemistry, and Biology. Grade XI students are selected because they are at a formal thinking stage that allows them to

participate in scientific activities such as observation, experimentation, and scientific reasoning, while teachers are selected based on a minimum of three years of teaching experience and involvement in the implementation training of the Independent Curriculum (Sugiyono, 2022).

This research begins with a preparatory stage which includes the preparation of instruments, validation by science education experts, and coordination with the school. The implementation stage was carried out by applying a scientific approach in learning mathematics and mathematics for four meetings. Before implementation, students are given a pretest to measure initial ability, while after learning is completed, they are given a posttest to measure the improvement in learning outcomes. During the activity, the researcher made direct observations on the implementation of learning to assess the implementation of scientific stages, namely observing, questioning, trying, reasoning, and communicating. Observations were carried out using structured observation sheets that recorded teacher activities and students' active participation in the learning process. In addition, students were given a questionnaire to find out their perception of scientific learning, including aspects of involvement, motivation, and interest in MIPA subjects. In-depth interviews were also conducted with six MIPA teachers to explore their experiences, strategies, and obstacles they faced in applying scientific approaches in the classroom. Interviews are conducted in a semi-structured manner so that researchers can obtain more in-depth information about the learning practices that occur.

The data collection is also equipped with documentation in the form of photos of learning activities, student work results, Learning Implementation Plans (RPP), and teachers' reflection notes as authentic evidence of the application of scientific approaches. Quantitative data obtained from test results were analyzed using descriptive statistics to determine the distribution of scores, averages, and improvement in student learning outcomes. The improvement in learning outcomes was analyzed using the N-Gain formula according to Hake (1998) to determine the effectiveness of learning in the high, medium, or low categories. Meanwhile, qualitative data from observations, interviews, and documentation were analyzed using the (Miles et al., 2014) model which included three stages, namely data reduction, data presentation, and conclusion drawn. Data reduction is carried out by selecting and focusing information relevant to the research objectives, data presentation is carried out in the form of thematic narratives, while drawing conclusions is

carried out through in-depth interpretation to find patterns, meanings, and relationships between findings in the field.

The results of the two types of data were then integrated through a triangulation method process to obtain a more complete understanding of the effectiveness of MIPA learning through a scientific approach at SMA Negeri 5 Karawang. Quantitative data provides empirical evidence of improved student learning outcomes after participating in scientifically based learning, while qualitative data provides an in-depth picture of how the learning process takes place, factors that support and hinder the application of the approach, and teachers' and students' perceptions of its benefits. Thus, the combination of these two approaches results in a comprehensive understanding that not only describes the effectiveness of learning in terms of outcomes, but also in terms of the quality of the process and the learning experience that occurs in the classroom.

RESULTS AND DISCUSSION

The Effectiveness of Scientific Approaches to Student Learning Outcomes

Based on the results of quantitative data analysis obtained from the learning outcome test before and after the application of the scientific approach to mathematics and natural sciences subjects at SMA Negeri 5 Karawang, it is known that there is a significant increase in learning outcomes in grade XI students of the MIPA program. The average pretest score of students from the three classes that were the subject of the study (XI MIPA 1, XI MIPA 2, and XI MIPA 3) was 70.15, while the average posttest score increased to 82.01. Thus, there was an average increase of 16.9% after learning based on scientific approaches was applied.

The calculation of N-Gain shows a value of 0.47, which falls into the moderate category according to the classification of Hake (1998). This indicates that the application of scientific approaches has a positive impact on improving student learning outcomes, even though it has not reached the high category. This improvement is mainly seen in the ability to scientific reasoning and the application of concepts in the context of everyday life.

Table 1. Average Student Learning Outcomes Before and After the Implementation of the Scientific Approach at SMA Negeri 5 Karawang

Class	Number of Students	Pretest Average Score	Posttest Average Score	Increase (%)	N-Gain	Category
XI MIPA 1	30	69,80	81,60	16,9	0,46	Keep
XI MIPA 2	30	70,40	82,30	17,0	0,48	Keep
XI MIPA 3	30	70,25	82,15	17,0	0,47	Keep
Total Average	90	70,15	82,01	16,9	0,47	Keep

These results show that the scientific approach is able to consistently improve student learning outcomes across the classroom. Although the effectiveness category is still moderate, the even increase indicates that this approach is relevant and can be widely applied in the context of MIPA learning at the high school level.

Further analysis of the improvement of each cognitive aspect was carried out to find out which dimension of ability experienced the most development. Based on the results of the analysis, the highest increase occurred in the reasoning and application aspects, while the lowest increase was in the recall aspect.

Table 2. Improvement in the Average Score of Each Cognitive Aspect of Class XI Students of MIPA SMA Negeri 5 Karawang

Cognitive Aspects	Average Pretest	Posttest Average	N-Gain	Category
Remembering (C1)	72,10	78,50	0,33	Keep
Understanding (C2)	69,70	81,30	0,46	Keep
Apply (C3)	67,80	83,60	0,52	Keep
Reasoning (C4)	65,50	84,90	0,55	Medium–High
Evaluate (C5)	66,40	82,10	0,47	Keep

From the table above, it can be seen that reasoning ability (C4) shows the most significant improvement. This is because the scientific approach directly trains students to think scientifically through the stages of observing phenomena, identifying problems, conducting experiments, interpreting data, and concluding observation results.

This finding is in line with the opinion of Sani (2019) who states that the scientific approach places students as active subjects in building knowledge based on direct experience, rather than just receiving information from teachers.

In addition to the test results, observations of the learning process show that most teachers have carried out the stages of the scientific approach quite well. However, the stages of questioning and reasoning (associating) are still the most challenging parts to develop consistently in the classroom.

Table 3. Results of Observation on the Application of Scientific Approach Stages in Mathematics and Natural Sciences Learning at SMA Negeri 5 Karawang

Stages of the Scientific Approach	Average Score (Scale 1–4)	Category
Observing	3,6	Excellent
Questioning	2,8	Enough
Experimenting	3,5	Good
Associating	3,0	Enough
Communicating	3,4	Good
Total Average	3,26	Good

In general, the implementation of scientific-based learning at SMA Negeri 5 Karawang is in the good category. Teachers show high competence in managing observing and experimenting activities, but still have difficulty in encouraging students to ask in-depth scientific questions and develop data-driven reasoning. Limited learning time and laboratory facilities are the main inhibiting factors. Based on interviews, several teachers said that experimental activities are often adjusted to the availability of tools and materials at school.

These findings are in line with the results of research by (Muslichah, 2021) and (Afriyani et al., 2022) which show that the limitations of laboratory facilities and the lack of teacher training are factors that hinder the implementation of scientific approaches in secondary schools. Nevertheless, students' enthusiasm for learning increased significantly. Based on the results of the questionnaire, 83% of students stated that scientific learning made them more interested in mathematics and natural sciences lessons, and 78% of students felt that they understood concepts better because they were directly involved in experimental activities and group discussions .

Overall, the results of this study show that the application of scientific approaches in learning mathematics and mathematics at SMA Negeri 5 Karawang is classified as effective in the medium category. Improved learning outcomes, active student participation, and positive perception of learning activities are the main indicators of the success of this approach. The scientific approach helps students relate scientific concepts to real phenomena in the surrounding environment, so that learning becomes more contextual and meaningful.

However, its effectiveness can still be increased if teachers receive advanced training on questioning and reasoning strategies, and if schools strengthen laboratory facilities and provide special time for guided experiments. Collaboration between MIPA teachers in designing project-based learning that is in line with the scientific approach is also recommended so that the learning process not only improves the cognitive aspect, but also the students' scientific and collaborative thinking skills in a sustainable manner (Nuraini & Syahputra, 2022).

Student Learning Activities in Mathematics and Natural Sciences Learning Through a Scientific Approach at SMA Negeri 5 Karawang

The results of observations on student learning activities during the MIPA learning process using a scientific approach at SMA Negeri 5 Karawang showed a significant increase in all stages of the scientific process. Student activity was measured using an observation sheet with five main indicators according to the stages of the scientific approach, namely observing, questioning, experimenting, associating, and communicating (Rusman, 2021).

Based on the data from observations in the three classes that were the subject of the study, it is known that the level of student involvement increased sharply after the application of the scientific approach. Before implementation, most students tend to be passive, just taking notes and listening to the teacher's explanations without much interaction. However, after the scientific approach was applied, students looked much more active in the learning process. They were involved in observation activities, discussed, conducted simple experiments in the laboratory, and delivered their findings orally in front of the class with enthusiasm.

Table 4. Increasing Student Learning Activities at Each Stage of the Scientific Approach at SMA Negeri 5 Karawang

Stages of Activity	Before the Scientific Approach (%)	After the Scientific Approach (%)	Increase (%)	Activity Categories
Observing	70	88	+18	Tall
Questioning	61	84	+23	Tall
Experimenting	65	86	+21	Tall
Associating	63	85	+22	Tall
Communicating	67	86	+19	Tall
Average	65,2	85,8	+20,6	Tall

The most prominent increase in student activity occurred in the questioning and reasoning aspects, which shows that scientific approaches are effective in fostering students' critical and analytical thinking skills. Questioning activities that were previously only carried out by certain students have now become routine activities that involve most students. Students are getting used to asking meaningful questions related to the phenomenon observed in the classroom and in the surrounding environment.

In addition, associating activities have also increased significantly. Students not only observe and record the results of experiments, but also try to connect the data with the theories that have been learned. For example, in learning chemistry about substance reactions, students conduct simple experiments to observe changes in color and precipitation, and then reason the relationship between the results of the experiment and the concept of chemical reactions.

However, in the aspect of communicating, students still need guidance in compiling scientific reports and conveying the results of observations with a consistent structure. Some students have difficulty in using scientific terms and writing conclusions logically. Nonetheless, students' enthusiasm for discussing and presenting shows a marked improvement in their scientific communication skills (Hosnan, 2016).

These findings strengthen the opinion of Hosnan (2016) that scientific approaches are effective for developing higher *order thinking skills* because they actively involve students in the process of searching for and discovering concepts. This process also encourages interaction and collaboration between students, making learning no longer one-way, but interactive, collaborative, and discovery-based learning.

Teachers' Competencies in the Implementation of Scientific Approaches at SMA Negeri 5 Karawang

The results of observations and interviews with six MIPA teachers at SMA Negeri 5 Karawang show that teachers' competence in implementing scientific approaches has developed quite well. Teachers are more skilled in designing scientifically based learning, facilitating simple experimental activities, and guiding students to think logically and scientifically.

However, some challenges are still found, especially in the stage of communicating learning outcomes. Some teachers admitted that it was difficult to guide students in compiling scientific reports and conveying the results of observations in good scientific language. This is in line with the findings of Astuti (2020) who stated that the scientific communication skills of high school students require explicit and continuous practice in order to develop optimally.

Table 5. Results of Observation of Teacher Competence in Scientific Learning at SMA Negeri 5 Karawang

Aspects of Teacher Competence	Average Score (Scale 1–4)	Category
Learning Planning	3,7	Excellent
Learning Implementation	3,4	Good
Mastery of MIPA Materials	3,5	Good
Class Management	3,3	Good
Use of Experimental Media and Tools	3,2	Good
Guiding Scientific Communication	2,9	Enough
Total Average	3,3	Good

The results of the observation show that learning planning is the strongest competency aspect. Most teachers have prepared a Learning Implementation Plan (RPP) by integrating all scientific stages completely, from observing activities to communicating. Teachers are also increasingly creative in utilizing alternative learning resources such as school environments, simple equipment, and digital media to support light experimentation.

However, the teacher's ability to guide students at the stage of scientific communication is still quite sufficient. The teacher said that this stage often takes longer than planned because students still need guidance in organizing results and writing reports. In addition, some teachers still find it difficult to relate the results of experiments to abstract concepts in physics and chemistry that demand deep conceptual reasoning.

These obstacles show the need to increase the capacity of teachers through continuous training on inquiry-based learning and science process skills. With adequate training, teachers will be better equipped to implement learning strategies that emphasize students' active engagement.

In general, improving teachers' competence in applying scientific approaches has a positive impact on learning outcomes and student activities. Teachers who act as facilitators, motivators, and supervisors are able to create a participatory, creative, and meaningful learning atmosphere.

This finding is in line with the opinion of Rusman (2021) who emphasized that teachers are a key factor in the successful implementation of the 2013 Curriculum. Without teachers' readiness and competence in understanding and implementing scientific measures, learning risks returning to the conventional *teacher-centered learning* pattern. Therefore, strengthening teacher competence through training, academic supervision, and a professional learning *community* is a strategic step to maintain the sustainability and quality of the implementation of scientific approaches at SMA Negeri 5 Karawang (Budiyono & Nurhadi, 2021).

CONCLUSION

Based on the results of research on the application of scientific approaches in learning mathematics and mathematics at SMA Negeri 5 Karawang, it can be concluded that this approach has proven to be effective in improving learning outcomes, student learning activities, and teacher competence.

First, from the aspect of learning outcomes, the application of scientific approaches is able to significantly increase the average student score. The average pretest score of 70.15 increased to 82.01 in the posttest with an average increase of 16.9% and an N-Gain value of 0.47 which was classified as a medium category. The highest improvement occurred in the aspects of reasoning and applying concepts, which shows that this approach is effective in developing students' critical and analytical thinking skills towards the scientific phenomena studied.

Second, from the aspect of student learning activities, the observation results show an increase in student involvement in all stages of the scientific process. Observing activity

increased from 70% to 88%, questioning from 61% to 84%, trying from 65% to 86%, reasoning from 63% to 85%, and communicating from 67% to 86%. The average increase of 20.6% showed that students became more active, dared to ask questions, were able to think scientifically, and were enthusiastic in discussing and conducting simple experiments. The scientific approach succeeds in creating an interactive, collaborative, and contextual learning atmosphere, in accordance with the characteristics of 21st century learning.

Third, from the aspect of teacher competence, the observation results showed an average score of 3.3 (good category). The aspect of learning planning (3.7) was the most prominent, followed by mastery of mathematics and natural sciences materials (3.5), the implementation of learning (3.4), as well as classroom management and the use of experimental media (3.2–3.3). However, the aspect of guiding scientific communication (2,9) is still quite sufficient and requires improvement through continuous training. Teachers need to strengthen their ability to guide students in compiling experimental reports, using scientific language, and relating findings to theory.

Overall, this study confirms that the scientific approach is effectively applied in the learning of mathematics and mathematics at SMA Negeri 5 Karawang. This approach not only improves students' academic achievement, but also fosters learning independence, curiosity, and high-level thinking skills (HOTS). However, its effectiveness can still be improved through strengthening laboratory facilities, continuous teacher training, and collaboration between MIPA teachers in designing project-based learning and guided experiments. With these steps, the scientific approach has the potential to be the main strategy in improving the quality of MIPA learning at the high school level in a sustainable manner.

Suggestion

1. Improving the Professional Competence of Teachers

Senior high schools in Karawang Regency are advised to improve the MIPA teacher training program which focuses on the application of scientific approaches, especially in developing the reasoning stages and communicating learning results. Inquiry-based approaches and *project-based learning* can be used as supporting training so that learning becomes more meaningful.

2. Improvement of Facilities and Laboratories of Mathematics and Natural Sciences

Schools need to enrich the tools and materials of laboratory experiments, as well as provide digital-based and contextual learning media so that students can more easily understand abstract concepts through hands-on experience.

3. Support from the Education Office and School Principals

The Karawang Regency Education Office together with the school principal need to strengthen academic supervision and periodic evaluation of the implementation of scientific approaches in the classroom. Support in the form of a teacher learning community can encourage innovation and sustainability of scientific practices in high schools.

4. Advanced Research

It is recommended that further research be conducted to review the relationship between the application of scientific approaches and the formation of scientific character, science literacy, and 21st century skills such as critical thinking, collaboration, and creativity. The results of the research can be the basis for the development of a more adaptive MIPA learning policy at the high school level.

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