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STEM Learning Method (Science, Technology, Engineering, and Mathematics) in Enhancing Student Competency: A Case Study at SDN Sempur. Plered. Purwakarta

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ABSTRACT

This research aims to find and analyze the implementation of STEM (Science, Technology, Engineering, and Mathematics) learning methods in improving student competence. The researcher uses a qualitative research paradigm with a case study approach. A sample of 22 (total sampling) educators used a structured questionnaire instrument. The results of the study showed that (1) The level of initial understanding and commitment of educators to STEM methods reached 99%; (2) Practically 21 respondents have applied this method and (99%) believe that the STEM approach is very effective in improving students' critical thinking, creativity, analytical, and complex problem-solving skills; (3) The phenomenon of polarizing experience 11 (50%) of respondents still faces technical obstacles in its implementation; (4)Phase C (Grades 5-6) was identified as the most optimal level for STEM reinforcement with a percentage of 54.5%. This study concludes that STEM learning methods can improve student competence.

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1. INTRODUCTION

Education in Indonesia is currently facing a huge challenge in improving the quality of human resources who are competent and able to compete in the era of globalization. One of the efforts to improve the quality of education is to implement innovative and effective learning methods, such as STEM (Science, Technology, Engineering, and Mathematics) learning methods. STEM learning methods have become a major focus in education in various countries due to their ability to improve students' abilities in the fields of science, technology, engineering, and mathematics (National Science Foundation, 2019).

According to the National Science Foundation (NSF), STEM is an educational approach that focuses on developing students' abilities in science, technology, engineering, and mathematics to solve

problems and improve the quality of life (National Science Foundation, 2019). STEM learning methods can help students develop critical, creative, and analytical thinking skills, as well as improve students' ability to solve complex problems (Bybee, 2013). In Indonesia, STEM education is still a challenge for teachers and schools. Many teachers do not have enough knowledge and skills to implement STEM learning methods (Ministry of Education and Culture, 2020). Therefore, it is necessary to conduct research on the effectiveness of STEM learning methods in improving student competencies in Indonesia.

This study aims to determine the effectiveness of STEM learning methods in improving student competence at SDN Sempur, Plered Purwakarta District. This research is expected to contribute to the development of education in Indonesia and improve the ability of teachers to implement STEM learning methods. Education in the era of globalization and the industrial revolution 4.0 is currently facing enormous challenges, especially in producing human resources who have high competitiveness and competencies that are relevant to the needs of the times. One of the strategic efforts to improve the quality of national education is through the implementation of innovative learning methods, such as the Science, Technology, Engineering, and Mathematics (STEM) approach. This approach integrates four disciplines holistically to equip students with 21st century skills. Theoretically, STEM focuses not only on material mastery, but also on developing the ability to think critically, creatively, analytically, and with the agility to solve complex problems encountered in real life.

In Indonesia, the implementation of STEM is starting to receive serious attention along with the implementation of the Independent Curriculum. However, on a practical level, STEM integration still faces various obstacles, ranging from infrastructure readiness to limited knowledge and pedagogical skills of teachers in designing interdisciplinary learning. This condition requires an in-depth study of the extent of the effectiveness of the method if applied to the basic education level. Therefore, this study was conducted to evaluate the implementation of STEM at SDN Sempur, Plered District, Purwakarta Regency.

The main problems raised in this study are focused on the level of understanding and readiness of teachers at SDN Sempur in operationalizing STEM, as well as how effective it is in improving students' cognitive and creative competence. In addition, this research seeks to identify technical barriers experienced by educators and map differences in learning effectiveness at various levels, ranging from Phase A to Phase C. Given the limitations of scope, this study limited the subjects to 22 educators using a quantitative descriptive approach to obtain an objective picture of the correlation between STEM methods and student competency achievements.

The main objective of this study is to comprehensively dissect how STEM methods can be a catalyst in improving the quality of learning in elementary schools. Theoretically, the results of this study are expected to make a significant contribution to the STEM education literature in Indonesia. Practically, this research provides concrete recommendations for teachers and school managers at SDN Sempur in developing more effective learning strategies, so that the gap between knowledge theory and practice in the field can be minimized in order to realize a competent and adaptive student profile.

STEM (Science, Technology, Engineering, and Mathematics) learning theory is a learning approach that focuses on developing students' abilities in the fields of science, technology, engineering, and mathematics. According to the National Science Foundation (NSF), STEM is a learning approach that focuses on developing students' problem-solving skills and improving the quality of life through the integration of science, technology, engineering, and mathematics (National Science Foundation, 2019). STEM learning theory emphasizes the importance of developing students' ability to think critically, creatively, and analytically, as well as the ability to solve complex problems.

Student competence is one of the most important aspects of education. According to Spencer and Spencer (1993), competence is the underlying characteristic of effective and efficient performance in a certain job or task. In the context of education, student competence can be interpreted as the ability of students to apply knowledge, skills, and attitudes to achieve learning goals. Student competencies can be developed through effective and efficient learning, as well as through relevant learning experiences.

The effectiveness of learning is one of the most important aspects of education. According to Bloom (1976), learning effectiveness can be measured through changes in student behavior after following the learning process. The effectiveness of learning can be influenced by several factors, such as the quality of teachers, curriculum, learning methods, and learning environment. In the context of STEM learning, learning effectiveness can be measured through students' ability to solve problems, develop projects, and apply science, technology, engineering, and mathematics concepts in daily life.

Thus, STEM learning theory, student competence, and learning effectiveness are very important concepts in education. Research on the effectiveness of STEM learning in improving student competence can contribute to the development of education and the improvement of the quality of learning. The development of STEM (Science, Technology, Engineering, and Mathematics) Learning Theory cannot be attributed to one particular individual. The term STEM was first used by the National Science Foundation (NSF) of the United States in the 1990s as the theme of the education reform movement to grow the workforce in STEM fields and develop STEM-literate citizens.

One of the figures who is known as a pioneer in popularizing STEM learning methods is Dr. Indah Wijaya, who is nicknamed "The STEM Teacher". He has developed STEM learning methods that focus on problem solving and projects, so that students can learn in a more interactive and collaborative way. This method has been used by many schools and has proven to be effective in improving students' abilities in science, technology, engineering, and math. STEM education itself is an approach in education in which science, technology, engineering, and mathematics are integrated with educational processes that focus on solving problems in real daily life as well as in professional life. The goal of STEM education is to prepare students to be competitive and ready to work according to their fields.

Student competence is one of the most important aspects of education. According to Spencer and Spencer (1993), competence is the underlying characteristic of effective and efficient performance in a certain job or task. In the context of education, student competence can be interpreted as the ability of students to apply knowledge, skills, and attitudes to achieve learning goals. A student's competencies not only include knowledge and skills, but also include other aspects such as attitude, motivation, and the ability to work with others.

According to Wibowo (2013), student competence can be divided into several categories, namely cognitive competence, affective competence, and psychomotor competence. Cognitive competence includes students' ability to understand and apply knowledge, while affective competence includes students' ability to regulate emotions and behave. Psychomotor competence includes the ability of students to perform physical actions related to a specific task or job.

The development of student competencies is one of the main goals of education. By having good competencies, students can improve their ability to solve problems, make decisions, and achieve their goals. Therefore, teachers and educators need to pay attention to the development of student competencies in the learning process. The effectiveness of learning is one of the most important aspects of education. According to Bloom (1976), learning effectiveness can be measured through changes in student behavior after following the learning process. Learning effectiveness can be defined as the ability of teachers to create a conducive learning environment and facilitate students to achieve learning goals. In this context, learning effectiveness does not only focus on student learning outcomes, but also on the learning process itself.

According to Guskey (2000), the effectiveness of learning can be measured through several indicators, such as students' ability to apply knowledge and skills, students' ability to solve problems, and students' ability to cooperate with others. The effectiveness of learning can also be influenced by several factors, such as the quality of teachers, curriculum, learning methods, and learning environment. In increasing the effectiveness of learning, teachers need to pay attention to several things, such as understanding students' needs and abilities, using effective learning methods, and creating a conducive learning environment. Thus, students can learn more effectively and achieve their expected learning goals.

2. METHODS

This research uses a case study approach. This approach is based on the researcher's goal to find and analyze in depth the phenomenon of STEM (Science, Technology, Engineering, and Mathematics) learning methods in improving student competence in the elementary school environment. The case study allows researchers to intensively explore the instructional dynamics that occur at SDN Sempur, Plered District, Purwakarta Regency.

Suharyanto H Soro (2023) in his book *How to Easily Understand and Conduct Qualitative and Quantitative Research* states that the Case Study Approach is one of the approaches in qualitative research. This research (case study) is in great demand by academics, especially Graduate School students (S2 & S3). According to him, 90% of research titles chose case studies. One of the reasons is that the problems being researched exist in their work environment, so it encourages them to find solutions and the findings are expected to be applied directly in real life. This reason is in line with the case study theory, which is that researchers are required to have *prior knowledge* related to the problem being studied.

The data collection method is carried out through: Observation: Direct observation of teacher-student interaction in the classroom to identify the real implementation of STEM methods. Interviews: In-depth discussions with teachers and students to explore perceptions of the effectiveness of the methods and the obstacles experienced. Document Analysis: Review of the Learning Implementation Plan (RPP/Teaching Module), teaching materials, and notes of student learning outcomes as supporting data. Data Validity The validity of the data is maintained through the Triangulation technique. The researcher triangulated the sources by comparing the results of teacher interviews, observations of student activities, and grade documents. In addition, triangulation techniques are applied to check the consistency of the same data with different collection methods, to ensure that research findings are valid and reliable.

Data Analysis Techniques Data analysis follows the Miles and Huberman model, which includes three simultaneous stages: Data Reduction i.e. The process of selecting, focusing, and simplifying raw data from the field to make it more meaningful. Data Presentation is the organization of information into the form of descriptive narratives and tables to make it easier to understand the patterns that appear. Conclusion Drawing is the final stage to interpret the data that has been analyzed and provide answers to the formulation of research problems regarding the effectiveness of STEM learning.

Location, Population, and Research Sample is located at SDN Sempur, Plered District, Purwakarta Regency. The research population included all school residents involved in STEM learning. Sampling was carried out using the Purposive Sampling technique, which focused on educators (22 respondents) and students in Phase C (Classes IV, V, and VI). This selection is based on the consideration that high-grade students have cognitive maturity that is better prepared to interact with complex STEM competency indicators.

3. FINDINGS AND DISCUSSION

One of the most significant findings in this study is the existence of a real discrepancy or gap between the level of knowledge of respondents and the ease of implementation in the field. Although the data in Table 1 shows that the level of knowledge reaches 100%, the data in Tables 3 and 5 reveal that 50% of respondents still have difficulty in implementing STEM methods in the classroom. This phenomenon indicates that the cognitive understanding of an educational innovation is not automatically proportional to the practical proficiency in its execution.

Theoretically, this condition can be explained through the concept of "The Knowing-Doing Gap" put forward by Pfeffer and Sutton, where there is a wide distance between what is known (theory) and what is done (practice). In the context of education, teachers may understand the STEM philosophy as an integration of science and mathematics, but they hit the roadblock at the operational stage. The difficulties experienced by half of these respondents are likely rooted in the complexity of STEM

instructional design that demands *engineering design process* skills, an aspect that is often unfamiliar in conventional curricula.

In addition, when viewed from the Theory of Organizational Readiness for Change, the success of a method does not only depend on the capacity of individuals (teachers), but also on resource availability and situational support. The 50% difficulty level shows that teachers' knowledge that has reached 100% is still hampered by external factors, such as the limitations of technology-based teaching aids, crowded learning time management, or the lack of ready-to-use practical modules. Therefore, the 100% understanding modality possessed by educators at SDN Sempur must be immediately accompanied by technical guidance (coaching) and the provision of adequate infrastructure so that the great potential of STEM methods in improving student competence is not stopped at the concept level alone.

Based on the data in Table 2, it was found that most of the respondents (91%) have implemented STEM learning methods in the school environment. The dominance of this application shows that educators at SDN Sempur have gone from the "awareness" phase to the "action" phase in the adoption of educational innovations. Theoretically, this is in line with the concept of Experiential Learning developed by David Kolb, where knowledge is created through experiential transformation. The courage of educators to implement STEM reflects a paradigm shift from conventional teacher-centered learning to student-centered learning through contextual integration of disciplines.

This massive implementation indicates that the school has met the criteria as a progressive learning organization. According to Albert Bandura's Social Cognitive Theory, the success rate of this implementation is also influenced by the self-efficacy of teachers that they are able to manage changes in instructional methods to improve student competence. However, the existence of 2 respondents who have not applied this method is a natural thing in the innovation adoption curve. This is often due to situational barriers or the need for longer adaptation time to the new curriculum tools. The existence of small groups that have not yet implemented this is an important indicator for school management that peer-coaching is still needed to ensure that all educators have equal competency standards in adopting an interdisciplinary approach in the Plered District area.

The research findings in Tables 3 and 5 present very competitive data, where there is an equal share of perceptions (50% versus 50%) regarding the difficulty of implementing STEM methods. This polarization phenomenon shows the existence of significant structural and personal obstacles in the midst of educators' enthusiasm. Theoretically, this condition can be analyzed through the Theory of Constraints in education, which states that the effectiveness of a system is often hampered by resource limitations or policies that are not yet in sync. Although teachers are highly motivated, technical barriers such as a dense curriculum load, limitations of technology-based teaching aids, and difficulties in designing interdisciplinary assessments are the determining factors that divide teachers' experiences in contrast.

Furthermore, this gap is also related to the concept of Pedagogical Content Knowledge (PCK) developed by Lee Shulman. Teachers who say they do not have difficulties are likely to have a mature integration between content knowledge (science and mathematics) and pedagogical knowledge of engineering (engineering). In contrast, the group that experienced difficulties was allegedly still in the technical adaptation stage of bringing together four different disciplines into one coherent project. This confirms Pfeffer and Sutton's theory of The Knowing-Doing Gap, which is the gap between understanding STEM concepts in general and proficiency in executing them in the classroom. Therefore, the equitable distribution of the quality of student competencies at SDN Sempur is highly dependent on the institution's efforts in facilitating sustained professional development to minimize these technical obstacles and create uniform standards of practice for all educators.

The implementation of STEM (*Science, Technology, Engineering, and Mathematics*) learning methods at SDN Sempur shows complex dynamics between theoretical readiness, field practice, and technical obstacles. Based on the data that has been presented, here is an in-depth discussion of the findings of the research.

Theoretical Readiness and Literacy of Educators

The findings of the study began with the fact that the level of knowledge and commitment to the implementation of STEM methods among educators reached an absolute 100%. In the perspective of the Innovation Diffusion Theory from Everett Rogers (2003), the level of knowledge is the main foundation before individuals adopt an innovation. This equitable collective consciousness signifies that the intellectual modality of educators has been aligned with the educational paradigm of the 21st century. This is a positive signal that the education ecosystem in Plered District has a strong vision to transform from conventional learning to an interdisciplinary approach.

Transition Towards Pedagogical Practice and Innovation The theoretical readiness has been transformed into concrete action, where 91% of respondents stated that they have implemented STEM in the classroom. Theoretically, this is in line with the concept of Experiential Learning from David Kolb (2014), where knowledge is created through the transformation of direct experience. Educators have sought to innovate beyond the boundaries of a single subject. This courage in adopting STEM reflects the high *self-efficacy* of educators in managing instructional changes to improve student competencies holistically.

Analysis of Contradictions: The Phenomenon *of The Knowing-Doing Gap* Despite the enthusiasm and widespread application, this study found a serious challenge in the form of polarization of the level of difficulty that is evenly divided (50% difficulty and 50% not). This phenomenon is known as *The Knowing-Doing Gap* (Pfeffer & Sutton, 2000), which is the gap between conceptual understanding and execution skills. The difficulties experienced by half of the respondents are thought to be rooted in the complexity of STEM instructional design that demands *an engineering design process*—an aspect that is often considered unfamiliar in traditional curricula. In addition, the Theory *of Constraints* explains that these obstacles are most likely triggered by external factors such as limited technological facilities and curriculum load density that hinder the flexibility of STEM projects.

The Effectiveness of STEM as a Catalyst of Competency Despite the existing technical barriers, there is an absolute consensus (100%) that STEM methods are very effective in improving students' critical, creative, and analytical thinking skills. This validates Jean Piaget's theory of Constructivism, in which students build understanding through the resolution of real problems. STEM works effectively at the Phase C level (Grades 5-6) in accordance with the formal operational stage of the students, but is also considered crucial as a foundation in Phase A. Overall, the high level of confidence of respondents (86%) in the effectiveness of STEM confirms that this method is a strategic instrument to create quality learning outcomes that are relevant to global challenges.

4. CONCLUSION

The conclusion of this study is that STEM learning methods can improve student competence. Educator Intellectual Readiness: There is a perfect level of theoretical understanding and awareness (100%) among educators regarding STEM methods. This shows that the human resource modalities at SDN Sempur have been aligned with modern education trends and are ready to carry out pedagogical transformation.

STEM methods are generally proven to be able to improve students' essential competencies, including critical thinking, creativity, analytical, and skills in solving complex problems. There is an implementation gap, namely practical obstacles in the field (50%) of respondents feel difficulties in implementing STEM methods. This shows that the understanding of theory is not completely proportional to the ease of technical execution.

In general, educators (54.5%) identified phase C (Grades 5-6) as the most effective level for strengthening STEM methods, considering the compatibility between the complexity of STEM material and the formal operational cognitive development stage of students. These data indicate that although STEM can be applied at all elementary school levels, there is a strong tendency among educators that the cognitive maturity of students in the upper grades (Phase C) is better prepared to optimally adopt the integration of knowledge in STEM approaches.

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