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Analysis of Students' Problem-Solving Skills in Physics Learning Through a STEM-Oriented Direct Teaching Model

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Abstract
Problem-solving skills are one of the 21st-century skills that students must master, but most students still have not mastered them. This research aims to describe the implementation and obstacles to implementing STEM-oriented direct instruction to improve students' problem-solving skills. This research is descriptive and qualitative in analyzing students' problem-solving skills. The subjects of this research were 20 students in class XI MIPA. The tools used are sound wave teaching materials that have been validated, and research instruments are student response questionnaires, and researchers act directly as teachers. Data analysis is carried out by reviewing the results obtained in the field through interviews, observations, and a collection of other documents. The data analysis stages in this research used the Miles and Huberman model: data classification, data display, and data validation. It was concluded that the implementation of learning took place according to the STEM-oriented direct instruction syntax, and several factors hindered the improvement of students' problem-solving skills, including internal factors, namely from within the students, and external factors, namely from the teacher and school.
Keywords: direct instruction; problem-solving skills; STEM

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INTRODUCTION

Education is critical in educating the nation's future generations, according to Indonesian Law No. 20 of 2003. Education involves educators who can organize formal and non-formal education as lectures, teachers, or other teachers. The advancement of science and technology in the twenty-first century has significantly impacted many sectors of life, particularly education. Equipping students with 21st-century skills is critical in overcoming this difficulty (Makiyah et al., 2021; Olivares & Ceglie, 2020; Wardoyo et al., 2020). Physics is one of the subjects that require these skills. Physics primarily focuses on the natural events that occur around us and how we apply them to our daily lives to build knowledge, skills, and

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confidence (Citra et al., 2021; Franestian et al., 2020). This strategy requires students to enhance, correct, understand, and apply what they have learned. Physics learning is a science learning activity that includes methods, scientific attitudes, and outcomes (Erlinawati et al., 2019; Reddy & Panacharoensawad, 2017). Physics learning for students is expected not only to master concepts but also to implement concepts that have been understood in solving physics problems. However, classroom learning does not prioritize students' physics problem-solving skills and is more likely to focus on mastering concepts (Azizah et al., 2015). This situation is very contrary to the urgency of the problem-solving skills possessed by students.

Problem-solving skills are defined as an individual's ability to solve a problem or difficulties they are facing Saputra et al. (2022) stated that problem-solving skills are required in all courses taught to students, particularly physics at the senior high school level. The facts in the field reveal that students' problem-solving abilities remain low. According to the findings of Azizah et al. (2015) interviews and observations, students are still less able to link physics issues with physics concepts because physics learning places less emphasis on problem-solving, prompting students to struggle with problem-solving. This is supported by the findings of the original study conducted by researchers using interviews with physics teachers at SMA Negeri 2 Pandih Batu, where information was obtained that most students faced difficulties in solving problems because they did not understand the basics of physics. These students even asked the teacher for instructions on how to solve problems. In addition, students' reading materials only stick to the textbooks available by the school, making it difficult for students to obtain further information related to the material being studied. In the 21st century, it is possible to integrate technology with teaching materials so that learning in the classroom can be more effective and varied. Various efforts have been made to train students' problem-solving skills, including applying STEM-oriented direct teaching in physics learning.

The guiding principles of direct teaching are based on behavioral psychology and social learning theory, particularly Albert Bandura's modeling theory (Arends, 2012). Bandura argues that the majority of learning experienced by a person is achieved through modeling, namely imitating the experiences and behavior of other individuals (Suyidno, Haryandi, et al., 2021). The use of STEM-oriented direct teaching models is considered appropriate and effective in determining students' success. The direct teaching model is one of the learning models specifically designed to assist the learning process of students related to declarative and procedural knowledge that is well organized and can be taught through a gradual, step-by-step pattern of activities (Dewanti et al., 2020; Heriyanti & Gumay, 2018). STEM is an interdisciplinary method that combines science, technology, engineering, and mathematics, integrating academic principles with practical problems. STEM applications help students develop reasoning, research, thinking, teamwork, and creative skills that they may apply to all aspects of their lives (Erlinawati et al., 2019; Medová et al., 2022). STEM applications in education are more meaningful when used with the appropriate learning model, such as direct instruction.

STEM-oriented direct teaching is educator- or teacher-centered learning, where the educator is in full control during the learning and management of STEM teaching, and the level of learner autonomy is still low (Bano et al., 2018; Suyidno, Mahtari et al., 2021).

Based on the above problems, a more in-depth analysis of the implementation of STEM-oriented direct teaching to train learners' problem-solving skills will be conducted. A qualitative descriptive study will explore the teaching process along with the obstacles learners and teachers feel during the learning process. The results of this study are expected to share benefits by enriching teachers' knowledge and insights in implementing STEM-oriented teaching.

METHOD

The research design was descriptive qualitative research, which described, defined, and analyzed the thing under study (Arikunto, 2012; Novikov & Novikov, 2013). Qualitative descriptive methods are frequently employed to reveal the significance, patterns, and complexities of an event, concept, or process. In contrast to quantitative approaches, which emphasize measurement and statistical analysis, qualitative descriptive approaches prioritize contextual and interpretive understanding (Shirish, 2014). This study aimed to identify an overview of the implementation of STEM-oriented direct teaching to train students' problem-solving skills (Jayusman & Shavab, 2020). The research was conducted as a case study where the researcher acted as a teacher and a research instrument while implementing physics learning using STEM-oriented direct teaching. A total of 20 students in class XI MIPA SMAN 2 Pandih Batu, Pulang Pisau Regency, Central Kalimantan, even in the 2022–2023 semester, became the subject of this research. Types and sources of data were attributes related to certain objects and useful information that could be calculated and taken using data collection methods or tools (Rasyid et al., 2013). Primary data sources were obtained from interviews with teachers to analyze students' characteristics and learning barriers in class XI MIPA. Meanwhile, secondary data were obtained from the pretest-posttest results of students, which were taken from the intended school website. The device used is sound waves teaching material with STEM steps, which has been validated, is suitable for use in the teaching and learning process, is categorized as very valid, and has high reliability (Maisarah, 2022).

The instruments used in this study were learner response questionnaires and teacher interviews. The learner response questionnaire assesses various aspects of learning, including teaching methods, clarity of materials, classroom atmosphere, and teacher support (Upagade & Shende, 2010). Student questionnaire responses can offer in-depth insights into how they perceive learning, whether they feel engaged, and how well they understand the subject matter (Novikov & Novikov, 2013; Shirish, 2014). The student respondents' questionnaire contains 22 statements, divided into positive and negative, measuring ease, usefulness, efficiency, and problem-solving during learning. Meanwhile, interviews with teachers were conducted to highlight factors that may not be visible from the learners' perspective. Teachers can provide insights into their challenges, strategies, and how they adjust teaching methods according to learners' needs (Mashrukhin, 2010; Novikov & Novikov, 2013; Shirish, 2014). To obtain information about learning outcomes, obstacles during learning, and facilities at SMA Negeri 2 Pandih Batu, the researcher interviewed the teacher of class XI MIPA at SMA Negeri 2 Pandih Batu. This interview method allowed the researcher to quickly find out the responses and perspectives of the interviewees.

Method of Data Analysis

Data analysis was conducted by reviewing the results obtained in the field. These results were in the form of

interviews, observations, and other documents. This study's data analysis stages used the Miles and Huberman (1994) model. The activities carried out in this data analysis are data classification, data display, and data validation, as shown in Figure 1.

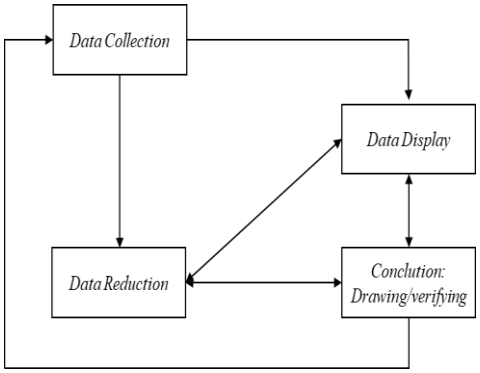

Figure 1 Data Analysis Stage of Miles and Huberman Model (1994)

RESULT AND DISCUSSION

STEM-oriented Direct Teaching Process

A Learning Implementation Plan was used to plan the learning activities before implementation. The lesson plan was designed for three meetings, including a pretest before learning and a posttest after the third meeting. At SMA Negeri 2 Pandih Batu, students followed the 2013 curriculum for class XI MIPA. Previously, there were observation exercises to identify pupils' characteristics and beginning knowledge of sound waves. After comprehending the learning system and recognizing student personalities, 20 students, 14 boys and six girls, were studied in three meetings held in class XI MIPA.

At the first meeting, the Learning Implementation Plan discussed sound wave characteristics, propagation speed, and classification. During the learning process, students paid attention but were not very active in asking questions; at the first meeting, they only explained the material and gave examples of problems. The following are the results of learning observations at meeting 1 in Table 1.

Table 1 Observation results of STEM-oriented DI at the first meeting

Teacher Behavior	Observation result
Communicates an outline of the STEM lesson objectives background information and prepares learners for learning	Accomplished
Demonstrates STEM procedural knowledge and skills correctly and gives feedback	Accomplished
Provides initial practice	Accomplished
Checks to find out if learners are doing the STEM task correctly and gives feedback	Accomplished
Prepare for advanced STEM tasks by focusing on transferring skills to complex situations.	Not Accomplished

Table 1 illustrates that, during learning, all phases of STEM-oriented direct instruction could be completed except for the final phase, which involved preparing advanced STEM assignments. This can happen owing to the short time available, but pupils require more time to learn thus it cannot be done. Table 2 shows the observations made at the first meeting on the problem-solving skills stages.

Table 2 Observation results of problem-solving skills stages at the first meeting

No	Problem-solving stage	Observation result
1	Visualize the problem	Some learners were able to visualize the problem
2	Describing physics concepts based on the problem	Learners were able to describe the problem
3	Planning a solution	Learners were able to plan the problem

No	Problem-solving stage	Observation result
4	Implementing the solution plan	Learners were able to implement the solution plan
5	Checking and evaluating	Some learners were able to check and evaluate the solution

Table 2 demonstrates that students completed two criteria for assessing problem-solving skills, namely characterizing the problem and designing a solution. In contrast, only a few students were able to complete the other three.

The lesson plan for the second meeting was created to cover the material of wave symptoms and resonance on strings. Learning revisits the material covered at the previous meeting, followed by the core material in which students learn to visualize occurrences or problems. When learning occurs, students pay attention but do not actively ask questions. The outcomes of learning observations during the second meeting are shown in Table 3.

Table 3 Observation results of STEM-oriented DI at the second meeting

Teacher Behavior	Observation result
Communicates an outline of the STEM lesson objectives, provides background information, and prepares learners for learning.	Accomplished
Demonstrates STEM procedural knowledge and skills correctly and gives feedback.	Accomplished
Provides preliminary practice.	Accomplished
Checks to determine if learners are doing the STEM task correctly and give feedback.	Accomplished
Prepare for advanced STEM tasks by focusing on transferring skills to complex situations.	Not Accomplished

Table 3 shows that during meeting 2, all DI-STEM phases could be carried out except for the last phase, namely preparing for further STEM tasks. This could occur due to the limited time given, and students need more time to learn it, so it could not be done. The results of the observation of the problem-solving skills stages at meeting 2 are in Table 4.

Table 4 Observation results of problem-solving skills stages at the second meeting

No	Problem-solving stage	Observation result
1	Visualize the problem	Some learners were able to visualize the problem
2	Describing physics concepts based on the problem	Learners were able to describe the problem
3	Planning a solution	Learners were able to plan the problem
4	Implementing the solution plan	Learners were able to implement the solution plan
5	Checking and evaluating	Some learners were able to check and evaluate the solution

Table 4 demonstrates that for each criterion to assess problem-solving skills, students were able to complete three tasks: defining the problem, creating a solution, and implementing the solution plan. Only a few students were able to implement the remaining three criteria.

The lesson plan discussed resonance material in organ pipes, intensity levels, and sound wave applications at the third meeting. Students had the opportunity to

experiment with making a simple acoustic guitar by dividing it into two groups, with each member having ten students to shorten the time. In this experiment, students were expected to be able to explain the process of sound and the factors that cause differences in the color of the sound on the guitar, which was then presented in front of the class. After completing the experiment, continue with the post-test. The following are the results of learning observations at the third meeting in Table 5.

Table 5 Observation results of STEM-oriented DI at the third meeting

Teacher Behavior	Observation result
Communicates an outline of the STEM lesson objectives background information, and prepares learners for learning	Accomplished
Demonstrates STEM procedural knowledge and skills correctly and gives feedback	Accomplished
Provides initial practice	Accomplished
Checks to find out if learners are doing the STEM task correctly and gives feedback	Accomplished
Prepare for advanced STEM tasks by focusing on transferring skills to complex situations.	Not Accomplished

Table 5 illustrates that during meeting 3, all DI-STEM phases could be completed except for the final phase, which involved planning for future STEM assignments. This could arise owing to the short time available, whereas students require more time to understand it; therefore, it could not be completed. Table 6 shows the results of observing the problem-solving skills phases at the third meeting.

Table 6 Observation results of problem-solving skills stages at the third meeting

No	Problem Solving Stage	Observation result
1	Visualize the problem	Some learners were able to visualize the problem. Learners were able to describe the problem
2	Describing physics concepts based on the problem	Learners were able to plan the problem
3	Planning a solution	Learners were able to implement the solution plan
4	Implementing the solution plan	Some learners were able to check and evaluate the solution
5	Checking and evaluating	Some learners were able to visualize the problem. Learners were able to describe the problem.

Table 6 reveals that students completed three of the problem-solving skills evaluation criteria: defining the problem, creating a solution, and implementing a solution plan. Only a few students were able to meet the remaining three criteria.

The results of the study stated that the low level of problem-solving skills of students in physics learning was caused by a lack of understanding of basic material and physical principles in formulas. This causes the ability to remember problem-based equations in physics to not be maximized. The implementation of physics learning using the STEM-oriented direct teaching model in the three meetings, except for the advanced training phase, went well. Students' learning activities in the sound wave material were active, and they positively responded to the teacher's questions. Even so, there were some obstacles, such as students who were less focused and less active in group discussions. The obstacle factors that interfere with learners' problem-solving learning, such as tactical barriers, the

impact of a teacher teaching, ontogeny barriers, namely mental readiness to learn, and epistemological barriers, namely the limited knowledge of learners in the context of the application (Brosseau, 1997 dalam Siswanto et al., (2017)). To overcome these obstacles, it was suggested that each student be given the opportunity and adequate time to solve physics issues during the learning process.

Learning Barrier

In the implementation of research at SMA Negeri 2 Pandih Batu, the class situation was quite good; students respected the researcher like a teacher. However, some learners needed special attention because they were less focused during learning. Implementing learning with the STEM-oriented direct teaching method went well except for the advanced training phase, which could not be implemented. In addition, the learners' problem-solving progress was almost nonexistent.

This was caused by several obstacles during the research, including (1) limited time; the time allocation is 2 JP or 2x45 minutes, but in reality, it is only given 2x30 minutes, so learning was not optimal, and there was some material that was not explained or tasks that had to be taken home; (2) students were active in class discussions but found some students who still could not be responsible if there were individual assignments. Learners tend to underestimate the task and answer at will; (3) Students' responses regarding the assignments distributed during class: students were active in doing it, but when the task was required to be taken home due to time constraints, some of the students did not do it; (4) During the research, the researcher did not meet directly with the physics teacher and only met with the operator who directed the researcher during the research. This happened because the physics tutor at SMA Negeri 2 Pandih Batu was a permanent teacher at SMP Negeri 4 Pandih Batu who helped teach at the high school due to a shortage of teachers, so he could not always be there.

The outcomes of each meeting showed little or no enhancement of students' problem-solving skills, indicating that students' skills remained low or poor despite successful learning implementation in each step. Adapted from (Siswanto et al., 2023) on impediments to problem-solving during the learning process.

Figure 2 shows that problem-solving skills are very important for students to master, but many of them find them difficult to learn, especially in physics material. The obstacles to learning problem-solving come from internal factors of learners, where they come to school with prior knowledge and skills, including problem-solving (Moreno, 2010; Siswanto et al., 2017). External factors such as teacher readiness and time constraints at school also play a role in this problem, with the lack of teachers who teach problem-solving in physics materials and limited learning time hindering the learning process to the fullest.

Efforts to overcome the problem of students' problem-solving ability can be carried out by focusing on understanding concepts and knowledge in learning. Learning in a context that develops learners' thinking skills will help improve problem-solving skills (Lin et al., 2020). Learners need to collaborate new knowledge with what they have learned before. In addition, science learning can also improve problem-solving skills by encouraging students to be creative, think critically, and think analytically (Becker & Park, 2011; Fortus, 2005; Ince, 2019). The results of Franestian et al.'s research (2020) identified several aspects that affect students' problem-solving skills, including experience, cognitive or thinking skills, and affective attitudes.

Barriers to adaptation to problem solving learning are shown in Figure 2.

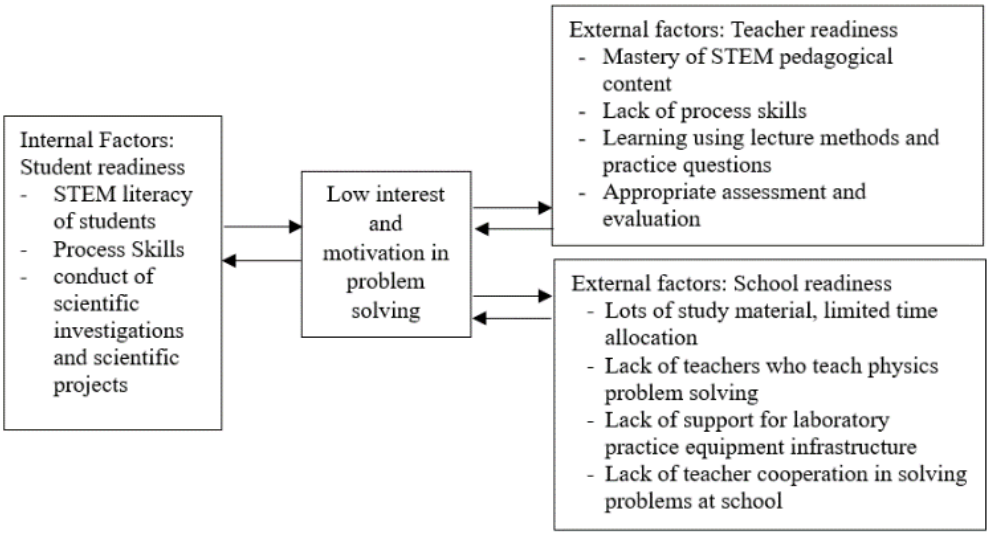

Figure 2 Barriers to problem-solving learning adaptation (Siswanto et al., 2023)

That Ogunleye (2009) suggested various efforts to overcome learners' inability to solve problems, such as giving enough homework and exams, using qualified teachers, providing review notes on how to solve problems, explaining the equations used, doing more laboratory work, providing good textbooks with examples of problem-solving, organizing tutorials and small group problem-solving periods, and repeating physics and math lessons to strengthen problem-solving.

Reddy and Panacharoensawad (2017) also make suggestions for overcoming learners' difficulties in solving physics problems, such as providing adequate homework and assignments, mock tests prior to the final exam, summary notes on how to solve physics problems, emphasizing basic equations, laboratory-based problem solving, good textbooks and tutorials, and revision on key physics topics and mathematical skills. The purpose is to improve students' capacity to learn physics.

The findings of this study indicate that the use of STEM in direct teaching could be one of the options for achieving student learning objectives. This type of learning can also assist pupils in improving their problem-solving skills through physics teaching.

CONCLUSION

Based on the results and discussion, it is concluded that learning physics through a STEM-oriented direct teaching model to increase students' problem-solving skills takes place well, and almost all phases of STEM-oriented direct teaching can be implemented. However, students' problem-solving skills were still categorized as low for some indicators, and there was almost no development during the application of STEM-oriented direct teaching. This is because there were factors that hindered learning, including internal factors, where students think that problem-solving, especially in physics material, is very difficult so that student's motivation to learn decreases, and external factors, where the time given for students to learn problem-solving skills are limited and the lack of teachers who teach problem-solving in physics material. The case study results may be used to improve learners' problem-solving and understanding of STEM-related problem-solving in everyday life.

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