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APPLICATION OF STEM EDUCATION TO ANALYZE AND SOLVE PHYSICS PROBLEMS IN SCHOOLS

Abstract

This study's objective was to describe students' problem-solving skills. The purposive selection method was used to pick the sample from among 65 participants from 11 classes. Data are gathered via a test of problem-solving aptitude. Its four indicators are problem identification, problem formulation, problem resolution, and problem assessment. Project-Based Learning (PjBL) in Science, Technology, Engineering, and Mathematics (STEM) is increasing efficacy, creating meaningful learning, and influencing student attitudes toward future career pursuits. Project-based learning with a STEM focus causes learning (PjBL). Students' abilities to plan, communicate, solve problems, and come to the best judgments from the difficulties presented are all improved by the learning. Students' abilities to plan, organize, negotiate, and make agreements about the tasks to be completed, who is responsible for each activity, and how the information will be gathered and presented can be developed through this learning.

Keywords: project-based learning (PjBL), science, technology, engineering and mathematics (STEM), physics education, problem-solving.

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МЕКТЕПТЕ ФИЗИКА ЕСЕПТЕРІН ТАЛДАУ ЖӘНЕ ШЕШУ ҮШІН STEM ОҚЫТУДЫ ҚОЛДАНУ

Аңдатпа

Бұл зерттеудің мақсаты орта мектеп оқушыларының физикалық есептерді шешу дағдыларын сипаттау. Зерттеу жұмысына 11 сыныптан 65 оқушы таңдалып алынды. Мәліметтер проблеманы шешу қабілетін тексеру арқылы жиналады. Оның төрт көрсеткіші – мәселені анықтау, мәселені тұжырымдау, мәселені шешу және мәселені бағалау. Ғылым, технология, инженерия және математика (STEM) саласындағы жобаға негізделген оқыту (PjBL) тиімділікті арттырады, мазмұнды оқуды жасайды және оқушылардың болашақ мансаптық ұмтылыстарына деген көзқарасына әсер етеді. STEM фокусы бар оқыту жобалық оқытуды тудырады (PjBL). Оқушылардың жоспарлау, қарым-қатынас жасау, проблемаларды шешу және ұсынылған қиындықтардан ең жақсы пайымдаулар жасау қабілеттері оқу арқылы жақсарады. Оқушылардың жоспарлау, ұйымдастыру, келіссөздер жүргізу және орындалатын тапсырмалар туралы, әрбір әрекетке кім жауап беретіні және ақпараттың қалай жиналып, ұсынылатыны туралы келісімдер жасау қабілеттерін осы оқыту арқылы дамытуға болады.

Түйін сөздер: Жобаға негізделген оқыту (PjBL), ғылым, технология, инженерия және математика (STEM), физикалық білім, есептер шығару.

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ПРИМЕНЕНИЕ STEM ОБУЧЕНИЯ ДЛЯ АНАЛИЗА И РЕШЕНИЯ ФИЗИЧЕСКИХ ЗАДАЧ В ШКОЛАХ

Аннотация

Цель этого исследования состояла в том, чтобы описать навыки решения проблем учащихся старших классов. Методом целенаправленного отбора была отобрана выборка из 65 участников из 11 классов. Данные собираются с помощью теста способности решать проблемы. Его четыре индикатора – идентификация проблемы, формулировка проблемы, решение проблемы и оценка проблемы.

Проектное обучение (PjBL) в области естественных наук, технологий, инженерии и математики (STEM) повышает эффективность, создает значимое обучение и влияет на отношение учащихся к будущей карьере. Обучение, ориентированное на STEM, создает обучение на основе проектов (PjBL). Способности учащихся планировать, общаться, решать проблемы и приходить к оптимальным выводам из представленных трудностей улучшаются в результате обучения. С помощью этого обучения можно развить способности учащихся планировать, организовывать, вести переговоры и договариваться о задачах, которые необходимо выполнить, о том, кто несет ответственность за каждое действие, и о том, как будет собираться и представляться информация.

Ключевые слова: проектное обучение (PjBL), наука, технология, инженерия и математика (STEM), обучение физике, решение задач.

Main provisions

Based on the study's findings, physics education students demonstrate advanced problem-solving skills, particularly in problem recognition and strategy planning, with strong implementation skills noted as well. However, their ability to evaluate solutions shows moderate development at this stage. The integration of Project-Based Learning (PjBL) in STEM-focused physics education is recommended for fostering collaborative teamwork and individual accountability. PjBL enables students to apply theoretical knowledge to real-world STEM challenges, promoting interdisciplinary learning across STEM fields. This approach prepares students for careers requiring integrated problem-solving skills. Effective implementation of PjBL necessitates teacher training, resources for project design, and diverse assessment methods to evaluate both collaboration and individual contributions.

Introduction

In recent years, physics problem-solving skills have attracted the attention of researchers. There is because prospective 21st-century teacher students are required to develop and master a variety of skills, including the capacity to solve problems. The goal of contemporary education is to produce student teachers who are capable of resolving issues that arise in both their personal and professional lives. They would have been expected to discover an easy solution to the issue as aspiring instructors. One of the 21st-century abilities on which physics learning is concentrated is the capacity for problem-solving. Students who are pursuing careers as professional physics teachers should be provided that material [1].

As aspiring teachers, students must possess the core skill of problem-solving. If students can use their fundamental knowledge to solve issues, they are said to be successful learners. Mathematical equations and techniques are not the only quantitative aspects of problem-solving that are stressed. However, it also places a strong emphasis on qualitative analysis components, such as selecting the appropriate concepts and guiding principles [2].

By tackling challenges that have practical applications, kids may study science, math, and engineering through STEM education. Application STEM education can be a substitute for scientific instruction in 21st-century classrooms [3]. Students who are exposed to STEM subjects may be encouraged to build, develop, and use technology while also developing their cognitive skills. STEM may teach students how to use technology and their knowledge to develop innovations that solve environmental problems [3].

Students are more likely to participate in activities that they believe are beneficial. In other words, before making a concerted effort, students must and prefer to believe in their own ability to comprehend the material. Students with strong self-efficacy feel they can effectively finish things. Students with high levels of self-efficacy, according to Pintrich and de Groot (1990), are more likely to persist with their goals. Furthermore, self-efficacy was identified as a major predictor of academic achievement. According to certain studies [4], students that are immersed in a learning environment that deals with real-life challenges tend to have good self-efficacy attitudes about the subject matter. Furthermore, students should be involved in the learning process in terms of cognitive and behavioral components, according to Linnenbrink and Pintrich's findings in 2003, for meaningful learning and increased self-efficacy. Other study discovered that STEM PjBL improves efficacy and promotes meaningful learning through student-directed inquiry.

Finding the physics principles that apply to the problem is one of the important steps in addressing a physics challenge. Students can be divided into two groups based on their problem-solving skills: those with high talents and those with low abilities. High-achieving students frequently employ arguments based on physics principles. They frequently assess potential solutions and make use of visual aids. On the other hand, less capable students are more likely to rely on quantitative evidence, such as the use of formulas to solve physics problems [5].

The steps involved in addressing physics issues include problem recognition, strategy implementation, strategy planning, and solution evaluation. These stages have been adjusted based on the problem-solving techniques proposed by Young, Freedman, Heller, and others. Table 1 lists the indications for each of these actions. These indicators are altered versions of [4] and [5]. The physics problem-solving skills utilized in this study are shown by this indication.

Table 1. Stages and Indicators of Physics Problem Solving Ability

Stage	*Indicator*
Recognizing the problem	*Identify problems based on basic concepts*
Planning strategy	*Determining the right concept for problem-solving* *Create a troubleshooting trial procedure*
Implementing strategy	*Solve problems according to plan* *Perform data analysis based on experimental results*
Evaluating solution	*Draw conclusions from the answers obtained and re-check the results obtained*

Science, Technology, Engineering, and Math (STEM) is one educational method that emphasizes problem-solving. STEM education-based learning in mathematics. STEM stands for Science, Technology, Engineering, and Mathematics, and it refers to an educational strategy. The science that future teachers' pupils study in this instance is physics. The use of technology is a supportive tool for teaching concepts and assisting pupils in understanding what they are learning. The goal of applying engineering is to teach students how to create, put things together, sketch, and do other things so that they may learn how to solve issues. The notion of science itself was also intended to be simplified by mathematics in a more organized and numerical manner.

In order to learn STEM, students must focus on a number of different aspects of the learning process, including: (1) posing questions and defining problems; (2) developing and using models; (3) planning and conducting investigations; (4) analyzing and interpreting the data; (5) using mathematics, information and computer technology, and computational thinking; (6) developing explanations (in science) and designing solutions (in engineering); (7) engaging in evidence-based arguments; and (8) obtaining, evaluating, and communicating data. Various techniques and learning models may be used to promote the implementation of STEM in education. That is as a result of STEM's integration. Numerous study findings describe PjBL, one of the learning models that may be used in STEM education. PjBL can force pupils to use their critical thinking and academic skills to solve difficulties [6].

PjBL is a problem-based learning approach that involves students in designing, solving problems, making decisions, or doing research [7]. PjBL can assist students in finding solutions to the difficulties presented, with a focus on the final products. Students' creations might take the shape of concepts or physical objects. Individuals or organizations may solve problems and design products. Working in groups can motivate students to collaborate while maintaining individual accountability for their work.Students can also manage their learning autonomously in groups, depending on the needs of their individual groups. Students can apply science and technology in product finishing. So that kids may comprehend indirectly how science and technology are used and help society.

The fact that students may select the tasks and activities they do during the learning process is another feature of PjBL. As they participate in inquiry, active discovery, investigation, and decision-making, students may be communicative and creative in the development of practical thinking. Experience and experimenting in the actual world are the foundation of knowledge. Additionally, PjBL makes learning relevant by tying new knowledge to previous experience. PjBL is a method that encourages all students to engage to the fullest extent possible [8].

According to early study in the form of learnt observations, previously taught knowledge did not develop problem-solving abilities. Explaining the physical facts that occurred and the theories that underpin and help solve them facilitates learning. Order for pupils to be less prepared to identify and address the challenges presented. Therefore, academics are interested in using the STEM-based PjBL model to help physics education students exercise their problem-solving abilities [9]. The purpose of this study was to characterize the problem-solving skills of students studying physics at the School Physics Laboratory.

The adoption of PjBL was anticipated to be a substitute for traditional scientific education in the twenty-first century. It is anticipated that STEM and PjBL will work together to help future physics instructors develop their problem-solving skills. Pre-service teachers must receive training in this area since they need to be able to solve problems in order to create engaging and fulfilling learning experiences for their students.

The description you've provided outlines a research study in the field of physics education, focusing on problem-solving abilities among physics course participants. Here's a breakdown of the key components and methodology of the study:

The primary goal of the study is to investigate and define problem-solving skills demonstrated by students enrolled in physics courses. The aim is to gain a comprehensive understanding of the intricacies involved in these skills and identify factors that contribute to their growth and development. The study employs a quantitative descriptive technique. This suggests that the research will primarily focus on collecting and analyzing numerical data to describe and understand the problem-solving abilities of physics students.

The study employs tests and surveys as data collection instruments. These tools are specifically designed to evaluate how proficient physics students are in solving problems. It's crucial to note that these instruments are quantitative in nature, implying that the data collected will consist of numerical scores or responses to structured questions.

The researchers use a purposeful sampling technique to select participants for the study. This means that they intentionally select students from the physics curriculum at various levels. The purposeful sampling approach allows the researchers to focus on specific groups of students that are most relevant to the research objectives.

The instruments chosen for data collection are tailored to assess problem-solving abilities in a range of physics-related contexts. This suggests that the study aims to explore how well students can apply their problem-solving skills in various scenarios within the field of physics.

Given the quantitative nature of the data, the analysis will likely involve statistical methods to describe and summarize the problem-solving skills of the participants. This may include calculating means, standard deviations, and other relevant statistical measures.

Overall, this research study seeks to provide a quantitative description of problem-solving skills among physics students. It uses purposeful sampling, specifically designed instruments, and quantitative analysis techniques to achieve its research objectives. The findings of this study could be valuable for educators and curriculum designers in improving physics education and enhancing students' problem-solving abilities in the field of physics.

Research methodology

This study uses quantitative descriptive methods. A variable or circumstance is intended to be described, interpreted, or explained in descriptive research. The purpose of this study is to describe the problem-solving skills of students studying physics at the School Physics Laboratory. The 65 participants in this study were all 2022 physics education students. Two classes made up the research subjects, and the purposive selection method was used to choose the sample. The research time was spent throughout the first and second terms of 2022.

The method of gathering data was done using a test of problem-solving skills. The tool has four indicators: identifying problems, formulating solutions, resolving issues, and assessing issues. The percentage score obtained from the computation of the Likert scale was employed in data analysis on a questionnaire. By assigning a score with a specified weight, the Likert scale has been used to gauge people's attitudes, views, and perceptions of an event. Equation 1 was employed to determine the average percentage.

$$P = \frac{f}{N} \cdot 100\% \quad (1)$$

P stands for the percentage average, f for the total score based on student opinions, and N for the highest possible score based on student perceptions. Table 2 [10] provides confirmation of the perception category of the pupils and the category of students' satisfaction.

Table 2. The Category of Students' Satisfaction

Percentage average	*Criteria*
85 – 100	*Very high*
70 –84	*High*
55 – 69	*Moderate*
40 – 54	*Low*
0 – 39	*Very low*

According to Table 2, analytical results are considered good if they have a value of 70.

Results of the study

The study was conducted as part of School Physics Laboratory instruction. Simple, yet relevant to the issue that arises in daily life, problems were given to the students. These issues take the shape of commonplace, straightforward physical facts. Students were also instructed to use the PjBL model to address similar challenges. Figure 1 depicts a sample of a problem that students were given.

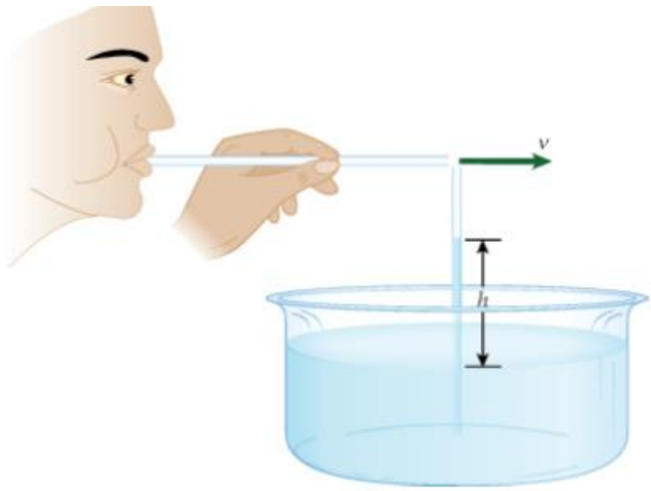

Figure 1. A straw is placed so that it stands vertically in a bowl of water

Task example: A straw is placed so that it stands vertically in a bowl of water. A second straw is placed perpendicular to the first. As you blow air into the second straw the level of water in the vertical straw rises, as shown in the figure. The straws are identical and have a diameter of d = 0.64 cm and length L = 20 cm. You are able to exhale 1.2 litres of air through he horizontal straw in 2 seconds, and the density of air is 1.29 kg/m^3.

a) Determine the speed of air v exiting the horizontal straw.

b) Solve for the pressure at the end of the straw where the blown air exists. Explain your reasoning for the values you use for each term in Bernoulli's equation (and any other equation(s) that you may use).

c) Solve for the height that the water rises in the vertical straw (labeled h in the figure above).

d) If you can maintain blowing the same volume of air in the same amount of time, how does the height of water change when you switch to a set of straws having half the diameter as before? That is, how does the water height depend on diameter of the straw? Explain your logic.

e) Given that the viscosity of air is $2 \cdot 10^{-5}$ Pa· s, what is the pressure difference required to blow 1.2 litres in 2 seconds through the straw?

In essence, the project-based learning approach aims to find solutions to challenging issues. In order to perform investigations and comprehend difficulties, this model is necessary[11]. PjBL is used in the classroom by splitting the students into various groups. Eight persons make up each group. Working in groups can motivate students to collaborate while maintaining accountability for their work. Additionally, students are able to independently regulate their learning according to the needs of each group member [11].

Process evaluation and evaluation of learning outcomes are carried out while applying the PjBL paradigm. Student progress reports on successful projects are used to evaluate processes in the classroom. A problem-solving ability instrument with four indications is used to evaluate the outcomes. That is problem-spotting, problem-solving, problem-solving, and evaluation. Table 3 displays the findings of the examination of physics education students' capacity for problem-solving.

Table 3. Results of Problem-solving Ability Analysis

Stage	*Indicator*	*Percentage*	*Criteria*
Recognizing the problem	*Identify problems based on basic concepts*	*84*	*High*
Planning strategy	*Determining the right concept for problemsolving* *Create a troubleshooting trial procedure*	*86*	*Very high*
Implementing strategy	*Solve problems according to plan* *Perform data analysis based on experimental results*	*77*	*High*
Evaluating solution	*Draw conclusions from the answers obtained and re-check the results obtained*	*69*	*Moderate*
Average		*79*	*High*

Discussion

Students were given a problem to solve after being given the problem. The number of problem agendas that are pertinent to the given problem that can be identified by the students is unlimited. Students were free to gather pertinent data by reading books, looking at things, speaking with experts, or doing their own experiments. Students are also given freedom and flexibility to create project plans that will work. Students plan how their project will go in groups.

Students create a schedule for the project's completion in order for it to be finished on time. At this point, students' problem-solving abilities have been honed to critical thinking, and they are proficient at estimating what needs to be done in terms of preparation and manufacturing so that the project may be finished on schedule. After creating the timetable, the following stage is to keep an eye on the project's development. This checks to determine if the project has been proceeding as expected. Students can use science and technology to their advantage in order to complete the project, which will help them grasp the uses and advantages of science and technology in daily life [11]. Students can learn how to apply their knowledge to use technology to tackle problems related to the environment by using science and technology in the classroom.

According to Table 3, pupils have a high level of recognition for the given issue. This is due to the fact that students were given straightforward issues that had real-world applications. in order for kids to recognize issues based on physics fundamentals. The capacity for strategy planning is very strong. Students can now choose the principles that will be applied to the situation at hand and design experimental methods to address it. Students can decide who will carry out the work stages and solutions, as well as the order in which they will be carried out. Furthermore, a high level of application of the technique is attained. At this point, students are capable of resolving issues using the experimental techniques they have gathered. Students collaborate to solve problems at this stage, but they are still each accountable for their own effort. The students carried out the experiment, collected the data, and then analyzed it. The kids' capacity for data analysis is very strong at this point.

The ability to assess the answer is currently at a reasonable level. At this point, students have a moderate level of proficiency in drawing conclusions from the results they have found. This is due to the fact that students merely draw conclusions from their experiment results and fail to relate them to the experiments' intended goals or to the physics principles that were employed to arrive at those conclusions.

According to data analysis findings, students studying physics education who participate in STEM-based PjBL learning have highly developed problem-solving skills. It is in line with earlier studies [12] and [13] that suggested the PjBL paradigm might enhance students' problem-solving skills. Another study by [13] revealed that using a STEM approach to teaching could enhance students' capacity for problem-solving.

Students get the chance to use science, math, and engineering to solve real-world problems through the use of PjBL that is STEM-based. Additionally, through group cooperation, students actively participate in ill-defined tasks that result in well-defined outcomes [14]. Students can use prototyping and science-based design to solve challenges through PjBL learning that is STEM-based. Students are urged to use more scientific creativity when solving problems once they have practiced using the four STEM disciplines [15]. Students who have developed problem-solving skills will be better able to use their ability to its fullest.

The culmination of this STEM-based PjBL learning is a presentation of the findings from the students' project assignments. The researcher determined the students' proficiency with technology based on the outcomes of the project presentation. When describing the problem-solving process, it appears that video editing was used in the presentation of project findings.

By implementing PjBL in multiple disciplines, students can also benefit from interdisciplinary learning experiences. They can see how concepts from different subjects can be integrated to solve complex problems, mirroring the real-world challenges they may encounter in their future careers. It's important for educators to receive appropriate training and access to resources when implementing PjBL effectively.

This includes designing meaningful projects, assessing student progress, and managing group dynamics. Professional development opportunities and collaborative planning can support teachers in adopting this approach. Consideration should be given to how student learning is assessed in PjBL. Assessment methods should align with the learning objectives and may include project presentations, written reports, peer evaluations, and individual assessments to measure both collaboration and individual performance.

Conclusion

Based on the study's findings, it can be said that physics education students have highly developed problem-solving skills. Four markers of problem-solving competency are present: a) problem recognition; b) strategy planning; c) strategy implementation; and d) solution evaluation. The students' skills are at a high level at this point in the process of identifying the issue. The pupil has very good ability in terms of planning and strategy.

Students abilities are at a high level when implementing the method, and they are at a moderate level when evaluating the solutions. STEM-based PjBL instruction can prepare students to use technology to apply their knowledge to solve environmental concerns. The additional information you've provided highlights the use of Project-Based Learning (PjBL) as a teaching approach in the context of physics education. Here are some key points to consider: PjBL encourages collaboration among students, where they work together on projects or problems. However, it's important to emphasize individual accountability within group projects. This ensures that each student contributes meaningfully to the project and learns from the experience. Individual assessment criteria can be established to measure each student's contribution.

Using PjBL with a STEM focus in the context of physics education aligns with the interdisciplinary nature of STEM fields. It allows students to apply their knowledge and problem-solving skills to real-world, STEM-related challenges, enhancing their understanding and engagement. The suggestion to employ STEM-based PjBL in other disciplines or courses that share similarities with the School Physics Laboratory is a valuable idea. PjBL can be adapted and applied to various subjects, not just physics. It's effective for promoting critical thinking, problem-solving, and collaboration in diverse educational contexts.

In summary, STEM-based Project-Based Learning is a valuable approach that encourages collaboration, critical thinking, and problem-solving skills in the context of physics education. Its applicability to other disciplines can enhance interdisciplinary learning and prepare students for the challenges of the modern workforce. However, successful implementation requires careful planning, teacher support, and a focus on both collaboration and individual accountability.

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