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Problem-Solving Skills on Prospective Teachers: Digital Problem-Based Learning in Geometry

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Abstract

This study was motivated by the failure of some formal educational institutions in Indonesia to apply the purpose of holistic Islamic education, resulting in the decadence of students' morality. The evidence of students' moral decadence is the high number of inter-student quarrels and the number of extramarital pregnancies in the last 8 years; that number is up 20 percent compared to the previous period. Holistic Islamic education should balance reason, morals, and physical students to produce intelligent graduates. Based on resourceful education, moral education, and physical education, this study discusses the implementation of holistic Islamic education purposes based on totally Muslim and truly intellectual in the IAIN Ponorogo postgraduate program. Using a qualitative approach, this study traces the concept of educational objectives in the IAIN Ponorogo postgraduate program and its implementation of education goals. The research period is limited to 2022, while the total number of informants is seven people. The data analysis uses content analysis methods such as data reduction, display, and conclusion. The data display uses domain analysis. The results of the study show that the three, that is, phase A (dhikr, thinking, and behavior), phase B (multidiscipline and multi-culture), and phase C (nobility, novelty, and solution) of implementations of holistic Islamic education purpose based on totally Muslim truly intellectual in the IAIN Ponorogo postgraduate program -, are relevant to the resourceful education, moral education, and physical education goals.

Keywords Holistic Islamic Education Purposes, Totally Muslim, Truly Intellectual IAIN Ponorogo Postgraduate Program

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1. INTRODUCTION

Problem-solving is necessary for school mathematics education(Dermawan et al., 2021). Its goal is to prepare students to utilize the theory they have learned to address difficulties in their daily lives (Nasution et al., 2018; Tabuyo, 2024). Problem-solving can be used to solve issues in various subjects, not just mathematics. Critical thinking is used to find, analyze, and interpret a problem's solution (Difinubun et al., 2024; Jäder et al., 2020). Furthermore, (Gahi et al., 2023)employ problem-solving as a component of procedural knowledge to improve understanding of mathematical ideas. Thus, someone with excellent problem-solving ability will have a good learning outcome (Difinubun et al., 2024; Syara et al., 2024) and can improve competence, productivity, and optimism (Gahi et al., 2023) and form a good character (Dermawan et al., 2021; Wiradnyana et al., 2024) and develop an attitude of independence and good team cooperation.

In the era of globalization and digitalization, problem-solving skills have become critical competencies that students require. The modern work environment requires individuals to be able to analyze complex problems and design effective solutions. Therefore, the education system must adapt by preparing a generation with critical thinking skills, creativity, and the ability to work collaboratively in problem-solving. (Andrini, 2024; Fatmanissa, 2023; Mahfuddin Nanang, 2022; Reno Warni Pratiwi et al., 2024)

Students who aspire to be elementary school teachers must be capable of problem-solving. Because these students are significant actors in the future of educational reform, they must stay current with educational trends, including problem-solving skills, which are part of 21st-century talents. Thus, higher education educators must provide potential elementary school teacher students with problem-solving skills, one of which is achieved through the DPBL learning paradigm. (Fitriani et al., 2021; Fitriati & Prayudi, 2021; Lai et al., 2015)

Prospective teachers must be able to solve problems and teach pupils problem-solving tactics that they may apply in their daily lives, both inside and outside school. Furthermore, prospective teacher students with problem-solving talents will be better equipped to handle issues that require critical thinking, adaptability, and the ability to discover new solutions to improve educational quality (Fatmanissa, 2023; Fatmawati & Murtafiah, 2018; Santhanam, 2018)

Based on observations and assessments done on 30 fourth-semester Elementary School Teacher Education Program students, the findings revealed that only 7 out of 30 students could solve the contextual problems, albeit imperfectly. This suggests that children's problem-solving abilities are still developing. In addition, using offline teaching materials without variation decreases students' interest in studying the material, which impacts their ability to solve problems related to geometry and measurement. Based on the description, a solution is needed to enhance students' problem-solving skills through engaging learning.

Based on the issues and needs analysis in the Elementary School Teacher Education Study Program at Nusa Cendana University identified the need for a primary school teacher education program related to problem-solving skills, i.e., 1) Because the mathematical problem-solving skills of pupils candidate elementary school teachers are still inadequate, it is vital to increase the ability to solve issues as a means of preparing students for primary school teacher education as 21st-century candidates. 2) Digital problem-based learning models have yet to be used to improve students' ability to solve mathematical issues. Problem-solving skills are so crucial in mathematical education that several strategies are employed to ensure that students and future teachers possess them. One option is to use a digital problem-based learning model to increase problem-solving skills (Fang et al., 2023; Laksmiyeny et al., n.d.; Pasca et al., 2024; Sulistyawati et al., 2023; Ulhaq & Juliwardi, 2023)

Learning using the PBL model will increase if combined with technology. (Car et al., 2019a) This learning is often referred to as digital problem-based learning (DPBL), where this approach offers several advantages in terms of accessibility and effectiveness compared to the PBL model. DPBL learning can be completed online at a convenient time and location, increasing the freedom of learning for future elementary school teacher students. Digital problem-based learning is a student-centered learning model that allows students to experience solving issues (S. Amin, 2019; K. A. Harahap et al., 2021; R. Harahap, 2021). It is a more effective learning model than any other. Each syntax in this model allows prospective teacher students to focus on problems, work individually or in groups to solve issues, discover strategies, address challenges, and evaluate the processes they have undergone. Digital problem-based learning encourages individuals to focus on identifying problems and analyzing, analyzing, and solving them. (Fatirul & Subandowo, 2021)

Learning with the DPBL paradigm also reduces anxiety for pupils who are unable to answer a problem because it can be explored alone. It enhances personal problem-solving abilities. For prospective primary school teachers, this is an important thing to implement, as it is a form of adaptation to the use of technology (Oliver, 2014). They can learn not only to accept concepts from teachers and friends but also through self-learning.

Research has shown that digital problem-based learning has several advantages, enabling students to recall and connect past knowledge with the knowledge acquired during the material analysis. This allows students to understand better what they have learned (Syekh et al., 2024.) Second, problem-based learning presents real-life problems, so students are interested in learning, and it helps them better their problem-solving processes (Mahfuddin Nanang, 2022; Nur et al., 2024). Third, through the use of problem-based learning, it will improve the collaboration and learning outcomes of students (Sipahutar, 2022)

Further stated by (Gasparič et al., 2024), digital learning problem-based learning provides innovation in learning. Learning is more effective because participants have time to explore material and receive continued material reinforcement at face-to-face meetings. At face-to-face meetings, participants will collaborate based on their initial knowledge to solve problems. On the other hand, they will need supervision to study the material, identify problems, find strategies, solve personal issues independently, and then discuss them with friends face-to-face.

Some studies show that the application of PBL models in integration with technology can improve problem-solving skills, including research by (Ayunda et al. 2024; Castro-Vargas & Cabana-Cáceres, 2024; Hadira et al., 2024; Mursyida et al., 2024; Suryaningtyas et al., 2020; Suwarto et al., 2023; Trianawati et al., 2023; Wardani & Sugandi, 2024; Wulandari, 2024; Yu et al., 2024; Zulfahrin et al., 2019). The research results show that the digital learning model based on problem-solving using e-modules can enhance problem-solving skills because students can flexibly use their time to identify problems, seek strategies, and apply them to solve them. In addition, students also have flexible time to arrange discussions with their peers, not just in the classroom. Then, in face-to-face meetings, students will receive reinforcement in discussions and collaboration with lecturers and peers to solve the given problems.

The originality of this study is the use of digital problem-based learning in the form of e-modules in geometry content. Although the problem-based learning model is not a novel concept, this study can help advance the use of digital problem-solving to improve the problem-solving skills of prospective teacher education students, one of the 21st-century skills that future teachers must have. While previous studies have focused on improving problem-solving skills using digital problem-based learning in different locations and subjects, this research targets explicitly enhancing problem-solving skills in mathematics for elementary school teacher candidates at Nusa Cendana University. Thus, the results of this research will serve as a reference for researchers and educators in the classroom who use the digital problem-based learning model to enhance problem-solving skills.

This study aims to determine the effectiveness of the digital problem-based learning model in improving problem-solving skills in geometry learning.

2. METHODS

This is quantitative research. The method of study adopted is quasi-experimental. We compared one or more treated experimental groups to one untreated comparison group. The nonequivalent control group design model was employed in this work as a quasi-experimental technique. Before treatment, the experimental and control classes will complete a pretest to assess their group problem-solving ability, followed by a posttest. The experimental classes use a digital problem-based learning model, whereas the control classes use a problem-based learning approach. The following phase is an efficiency test based on N-Gain results. It is intended to assess the efficacy of a digital problem-based learning model (DPBL) against mathematical problem-solving abilities. The PBL and DPBL models are implemented at each meeting using the following syntax: orienting students to the problem, organizing them for learning, directing individual and group investigations, developing and presenting outcomes, and assessing and evaluating the problem-solving process.

The next step is an efficiency test using N-Gain scores. It is designed to compare the effectiveness of a digital problem-based learning model (DPBL) to mathematical problem-solving ability.

Table 1. Digital Model Problem-Based Learning

Weeks	Mode of Learning	Learning Materials
1	Face-to-face	Pretest: Round and Flat Building Space, Volume, and Surface Area of Building Space
2	Online	Introduction, introduction of digital-based modules, technical use of digital-based modules, learning contract
3	Face-to-face	Concepts: rotating and extensive flat buildings
4	Online	Concepts: Volume and size of surface build space
5	Face-to-face	Concepts: Volume and size of surface build space
6	Face-to-face	Pretest: Round and Flat Building Space, Volume, and Surface Area of Building Space

Table 2. Model Problem-Based Learning

Weeks	Mode of Learning	Learning Materials
1	Pre-Test	Pretest: Round and Flat Building Space, Volume, and Surface Area of Building Space
2	Face-to-face	Introduction, introduction of digital-based modules, technical use of digital-based modules, learning contract
3	Face-to-face	Concepts: rotating and extensive flat buildings
4	Face-to-face	Concepts: Volume and size of surface build space
5	Face-to-face	Concepts: Volume and size of surface build space
6	Posttest	Posted: Round and Flat Building Space, Volume, and Surface Area of Building Space

This study's participants are students enrolled in the sixth semester of FKIP Universitas Nusa Cendana's Elementary School Teacher Education Program. There were 66 students in total. Cluster random sampling techniques were used. The class was divided into control and experimental, each with 33 students.

This study used tests and questionnaires. The tests evaluated problem-solving abilities before and after treatment. The courses will take place over four meetings in PBL and DPBL classes.

The digital problem-based learning model satisfaction questionnaire indicators include user experience and satisfaction. The indicators of the user experience aspect include the ease of understanding the DPBL concept, the interactivity of the DPBL model, the effectiveness in problem-solving, the attractiveness of the materials and resources, and the increase in motivation. The indicators of user satisfaction include satisfaction with learning using the DPBL model and the experience of participating in learning with the DPBL model. Table 3 illustrates how to assign a value or score to each answer using the Likert scale.

Table 3. Likert Scale

Score	Satisfaction Level	Description
5	Very satisfied/ Very effective/ Very interesting	Respondents are very satisfied with the statements provided.
4	Satisfied / Effective / Interesting	Respondents are happy with the statement.
3	Somewhat Satisfied, Fairly Effective, or Fairly Interesting.	Respondents do not have a strong opinion.
2	Less Satisfied, Less Effective, Less Attractive.	Respondents feel less satisfied with that statement.
1	Not Satisfied, Not Effective, or Not Interesting	Respondents were very dissatisfied with that statement

(Creswell, 2018; DeVellis, 2017)

Next, the following formula can be used to calculate the average satisfaction score of students participating in learning with the DPBL model.

$$The\ Score\ Obtained = \frac{Total\ Score\ Obtained}{Number\ of\ Questions}$$

Next, the obtained results are interpreted as follows:

4.21 - 5.00 = Very Satisfied, Very Effective, or Very Interesting.

3.41 - 4.20 = satisfied, compelling, or enjoyable.

2.61 - 3.40 = Fairly Satisfied, Fairly Effective, or Fairly Interesting.

1.81 - 2.60 = Less Satisfied, Less Effective, Less Attractive.

1.00 - 1.80 = Not Satisfied, Not Effective, or Not Interesting.

This study's data was analyzed using inferential statistics, which included prerequisite tests, difference tests, and N-gain. The prerequisite test employs the normalcy test. The t-test detects whether there is a difference in the average between two paired samples, whereas the N-Gain test evaluates the success of the digital problem-based learning model.

This study analyzed data using a t-test to compare the problem-based learning model with the digital problem-based learning model in geometry materials. The t-test formula is given below:

$$t = \frac{\overline{X_1} - \overline{X_2}}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Note:

t : Test the hypothesis

$\overline{X_1}$: average count of experimental classes

$\overline{X_2}$: average count of control classes

S^2 : variance

n_1 : the number of experiment classes

n_2 : the number of control classes

Next, the t-test results are interpreted using the following criteria:

H_0: Problem-solving abilities are similar to applying the problem-based and digital problem-based learning models in geometry education for prospective elementary school teachers. H_1: There is a significant difference in problem-solving abilities between applying the problem-based learning model and the digital problem-based learning model in geometry education for prospective elementary school teachers.

The choice to accept or reject the null hypothesis in this test is based on the following: 1. If the significance level exceeds 0.05, H_0 is received, and H_1 is denied. If the significance value is less than 0.05, H_0 is rejected, and H_1 is approved.

The next step is an efficiency test using N-Gain scores. It is meant to compare the effectiveness of a digital problem-based learning paradigm (DPBL) vs mathematical problem-solving ability.

$$Gain = \frac{Posttest - Pretest\ Score}{Maksimum - Pretest\ Score} x\ 100$$

The result of the n-gain calculation is then interpreted according to the criteria of Hake (1999).

Table 4. N-Gain Criteria

N-Gain Percentage	Criteria
100% – 71%	High
70% – 31%	Medium
30% - 1%	Low

3. FINDINGS AND DISCUSSIONS

This study aims to determine the effectiveness of applying digital problem-based learning methodology. N-Gain tests are used for effectiveness evaluations. Normality and homogeneity tests should be performed before N-Gain testing. Then, t-tests and N-gain tests are performed. The results of the normality tests are shown in Table 5.

Table 5. The result of the Normality Test

Types of Data	Groups	*Shapiro Wilk*		
		Statistic	**Df**	***Sig.***
Pretest	Control	0.657	33	0.065
	Eksperimental	0.731	33	0.084
Posstest	Control	0.976	33	0,080
	Eksperimental	0.834	33	0.10

Table 5 shows the normality test results from the data pretest and posttest. The significance values obtained from the test results of the data with SPSS > 0.05 can be used to conclude that the data from this study are typically distributed. Table 6 shows the results of the homogeneity tests.

Table 6. The result of the Homogeneity Test

Types of Data	*Levene Statistic*	*Sig.*
Pretest	7.146	0.071
Posttest	8.230	0.065

After conducting normality and homogeneity tests and meeting the criteria, the next step is the t-test. Table 7 shows the t-test results to determine the differences between applying the problem-based learning model and digital problem-based learning in geometry material.

Table 7. T-test for Posttest Control Class and Experimental Class

Mean	Std Deviation	Std Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
42.167	18.142	6.390	39.781	44,553	9.523	32	**.000**

Based on the data processing in Table 7, it is known that the sig (2-tailed) value is 0.000 < 0.05. This means that H_0 is rejected, which means there is a significant difference in students' problem-solving ability before and after using problem-based e-modules.

After performing the paired sample t-test, the N-gain test is performed to determine the category of improved problem-solving capabilities after using the problem-based e-module for surrounding material and flat-build spaces. The results of the n-Gain test analysis can be seen in Table 8.

Table 8. N-Gain test analysis results

Data	N	Rata-rata	
		Gain	%Gain
Pretest dan Post-test	33	**.6919**	69.19%

Based on the data in Table 7, the pretest and posttest averages of 0.69 or 69.19% in the medium category are obtained. Using a digital problem-based is average or somewhat effective.

Why is the digital problem-based learning model more effective than the problem-based learning model?

The combination of e-modules and problem-based learning models presented in both face-to-face and offline formats, referred to as the digital problem-based learning model, has been implemented in this research. This study was conducted in two different classes, the first class being called the control class and the second class being known as the experimental class. In the control class, learning is conducted using a problem-based learning model with face-to-face instruction. In contrast, the experimental class uses a blended learning approach with face-to-face and online instruction. In online mode, students utilize problem-based learning e-modules to study geometry content.

Learning using a digital problem-based learning model has been more effective than learning with a problem-based model. The findings obtained from the first DPBL learning model allow students to arrange the time and place to study independently. Second, this learning model makes students more interested in learning because it combines technology (e-module problem-based learning), which is relevant to student learning development today. Third, some students with auditory and visual learning types tend to be more collaborative and communicative in online learning. The same is stated by (Amin et al., 2021) that learning with the mobile blended problem-based learning model facilitates face-to-face and online learning.

On the other hand, learning using MBPBL provides flexibility, allowing students to study independently and freely determine the time and place of study. In addition, it was found that students experienced a decrease in anxiety by not studying in a room with other students, so even though they did not understand the subject, they could learn by adapting to their abilities and not being afraid to be mocked by other students. (Jaenudin & Murwaningsih, 2017) Learning to use DPBL can improve students' ability to operate IT. Furthermore, (Car et al., 2019) found that implementation of learning like this can save costs and foster an attitude of independence in learning.

Based on the results of this research, it was found that the learning model is one of the essential aspects that need to be considered in the learning process. As in this study, the learning model is used by teachers to provide instruction in achieving learning objectives. The learning model used is the digital problem-based learning model in geometry education, which can guide teachers in enhancing the problem-solving skills of prospective elementary school teacher students. The advantages gained from utilizing the digital problem-based learning model include the integration of technology into the use of problem-based learning models, whether conducted online or offline, as well as the use of e-modules in the learning process. Based on the results of this research, it is recommended that the digital problem-based learning model be used to equip prospective elementary school teacher students with technology-based learning to enhance their problem-solving skills. This is supported by (Fitriati et al., 2023), stating that teachers today must be equipped with 21st-century skills and technology-based learning to adapt to future educational changes that already utilize technology.

The research results indicate that learning through the digital problem-based learning model allows students to develop problem-solving skills. As explained in the previous discussion, problem-solving skills are essential for an individual to address fundamental issues by involving critical, logical, and systematic thinking. Problem-solving skills include the ability to identify problems, the skills to determine strategies and use them to solve problems, and the ability to evaluate problems. This aligns with the opinion of (Nico Pradana, 2024)) that individuals use problem-solving skills to resolve real-life issues and can apply the information they have acquired to new situations. In this study, the digital problem-based learning model enhanced that process. This is because every syntax of the digital problem-based learning model supports participants in achieving that. First, the syntax of problem orientation that independently uses PBL-based e-modules helps students focus on problem identification. In this syntax, students will independently watch videos in the e-module related to real problems concerning the perimeter and area of flat shapes and the volume and surface area of three-dimensional objects. The research results indicate that learning through the digital problem-based learning model allows students to develop problem-solving skills. As explained in the previous discussion, problem-solving skills are essential for an individual to address fundamental issues by involving critical, logical, and systematic thinking. Problem-solving skills include the ability to identify problems, the skills to determine strategies and use them to solve problems, and the ability to evaluate problems. This aligns with the opinion of (Nico Pradana, 2024) that individuals use problem-solving skills to resolve real-life issues.

Moreover, individuals can apply the information they have acquired to new situations. In this study, the digital problem-based learning model enhanced that process. This is because every syntax of the digital problem-based learning model supports participants in achieving that. First, in online learning, the syntax of problem-oriented learning that independently uses PBL-based e-modules helps students focus on problem identification. In this syntax, students will independently watch videos in the e-module related to real problems concerning the perimeter and area of flat shapes and the volume and surface area of three-dimensional objects.

Next, participants will answer questions in the e-module to help them identify the issues, such as what is known about the problem, what is being asked, and what strategies are used to solve it. Second, in online learning, the syntax organizers organize participants to learn, where participants independently study the problem-based tasks assigned by the lecturer. Participants will learn to identify problems within the problem-based tasks and be provided with materials related to the issues they will study independently. Third, the third syntax involves guiding individual and group investigations, which are conducted face-to-face. At this stage, participants will discuss findings related to problem identification and the material that has been studied independently. Participants will discuss problem identification findings and the material studied separately at this stage. Students will collaborate in groups to complete the assigned problem-based tasks. Fourth, the fourth syntax presents the discussion results face-to-face. At this stage, students will provide feedback on the results of other groups' discussions and compare their work with that of different groups. After that, in the final syntax, which is the analysis and evaluation of the solution process, students analyze and evaluate the process and results of problem-solving. The process carried out in this syntax offers several advantages, namely, *contextualization of real problems*.

The digital PBL model presents problems that are relevant to real-world situations. When students face issues that require solutions, they are compelled to think critically and develop innovative solutions. Digital technology allows these problems to be simulated interactively and dynamically, making the learning process more profound and realistic. *Second, Facilitation of Self-Directed Learning.* In digital-based PBL, students can explore problems independently with the support of digital tools such as e-modules, online learning platforms, and interactive software. This encourages them to think critically, design strategies, and make decisions independently, essential in problem-solving. *Third, collaboration through online platforms*. One of the advantages of digital learning is its ability to support remote collaboration.

In PBL, students often work in groups to solve problems. Technology enables them to collaborate through online discussion forums, shared documents, or project management platforms. This collaboration helps students learn to work as a team, communicate, and solve problems together. *Fourth, access to extensive resources*. Digital technology provides students with broader access to various information, data, and tools that can be used to solve problems. They can access journals, instructional videos, online simulations, and other relevant tools to support their analysis and solution processes. These abundant resources help enrich their understanding of the issues: *fifth, direct feedback and automatic assessment*. Digital platforms can provide students with immediate feedback, evaluating their performance in completing tasks and reflecting on the proposed solutions.

With quick feedback, students can promptly understand what they have done correctly or what needs improvement, allowing them to correct mistakes and optimize strategies for problem-solving quickly. *Sixth, time and place are flexible*. The digital PBL model provides flexibility for students to learn anytime and anywhere. This allows them to access learning materials and resources according to their own time and needs, enabling them to be more focused and independent in solving problems. *Seventh, Increasing Motivation and Engagement*. Interactive and engaging digital technology can enhance students' motivation to learn. Learning designed in games, simulations, or other digital activities makes students more involved and interested in completing the challenges presented. With higher engagement, their ability to solve problems also develops naturally.

4. CONCLUSION

The Digital Problem-Based Learning Model (DPBL) combines problem-based learning and e-modules implemented in learning mathematical materials and geometry hybrids. The DPBL model was implemented as one way to improve the problem-solving skills of prospective primary school teachers. The research used the N-Gain technique to determine the effectiveness of DPBL models on students' problem-solving skills. The result is an N-gain value of 0.69, which falls into the category quite effectively if interpreted using the N-gain criterion. Further qualitatively obtained is that this DPBL model is very relevant to the learning model in demand by students today because integrating technology into their learning makes it easier for students to study materials in different places and times. Students can set up a learning time that is adequate for them to learn. Furthermore, DPBL provides learning independence and a lack of anxiety when not knowing the material they are learning because they have time to learn repeatedly until they understand it. The other impact is that students' IT capabilities are increasing due to integrating technology into learning.

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