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Blended learning in mathematic: the fusion of GeoGebra and Edmodo for enhanced problem-solving abilities

Anton Nasrullah[1], Mimih Aminah[2], Umalihayati[3], Kurniati Rahmadani[4], Sri Adi Widodo[5], Mohamad Husni[6]

[1]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Bina Bangsa, Serang, Indonesia
[2]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Sebelas April, Sumedang, Indonesia
[3]Department of Management Education, Faculty of Teacher Training and Education, Universitas Bina Bangsa, Serang, Indonesia
[4]Department of Information Technology Education, Faculty of Teacher Training and Education, Universitas Bina Bangsa, Serang, Indonesia
[5]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Indonesia
[6]Department of Accountancy, Faculty of Economics and Business, Universitas Bina Bangsa, Serang, Indonesia

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ABSTRACT

This research investigates the effectiveness of problem-based mathematics learning through blended learning with the help of Edmodo and GeoGebra in improving problem-solving skills in mathematics learning. The primary motivation of this research is to develop a learning approach that can overcome challenges in solving mathematical problems. The method used in this study used a quantitative approach, and a quasi-experimental pre-test and post-test control group design was applied. This study involved 72 students in two semesters from a university in Banten, Indonesia, with 36 students in the experimental class (11 male and 25 female) and 36 in the control class (10 male and 26 female). Data was collected through problem-solving tests before and after the learning intervention—data analysis using paired t-tests and independent t-tests. The group using Edmodo-GeoGebra (BL-UEG) and the group Edmodo without GeoGebra (BL-EWG) experienced an increase in the moderate category. In conclusion, problem-based mathematics learning through blended learning with the help of Edmodo and GeoGebra can be an effective alternative learning model for improving students' problem-solving abilities in mathematics. Therefore, this approach deserves further exploration in learning settings.

Corresponding Author:

Anton Nasrullah
Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Bina Bangsa
Panancangan, Cipocok Jaya, Serang City, Banten, Indonesia
Email: anton.nasrullah@binabangsa.ac.id

1. INTRODUCTION

The 21st-century skills are ubiquitous in ongoing societal discussions about schools, education, and educational research fields [1]. In this context, scientific reasoning and argumentation, statistical literacy, or data-based reasoning are widely discussed to solve problems [2]. Every day, humans face issues considered simple and problems quite complicated or even make those facing them think and try hard to solve them.

According to several sources, a problem is a situation that requires a solution, but the path to the answer has yet to be found [3]–[5]. However, their problems can differ from person to person, depending on their level of development. A problem is a quantitative situation that requires a solution, and individuals must find a clear way out to get a solution [6]. Three commonly used problems for reviewing previously learned

skills or algorithms [5] are remembering, training, or exploring. These problems involve thinking and synthesizing from previously acquired knowledge and are often associated with problems requiring such skills.

According to Sloane [7], mathematics education emphasizes problem-solving as the main focus of learning activities at all levels. Higher education students need opportunities to tackle complex problems, reflect on their thinking, and apply development strategies to other contexts. By solving math problems, students develop critical thinking skills, persistence, curiosity, and confidence in unfamiliar situations outside the classroom. Good mathematical problem-solving skills encompass several elements, including understanding problem information, devising problem-solving strategies using mathematical procedures, and drawing logical conclusions based on the problem context. Students can be presented with problem-solving questions to enhance these skills.

Responding to the urgency of the need to boost productivity and competitiveness in the 21st century era, the government has utilized digital technology, and education has evolved into education 4.0 with various technological innovations, especially the implementation of information and communication technology (ICT) in the process of learning mathematics, as stated by Elsayary [8] educators must continue to train students to innovate using ICT in blended learning, which has received particular attention in recent years. Blended learning is effectively used to complement the learning process, and two of the tools used to support problem-solving in learning mathematics in a blended learning environment are Edmodo and GeoGebra.

Blended learning is an educational technique that combines in-person classroom instruction with online or digital learning resources [9]–[11]. Blended learning has several benefits in providing opportunities for instructors to incorporate various teaching strategies and technologies into their curriculum and teaching materials, making the learning experience more dynamic and exciting, one of which is using GeoGebra. GeoGebra is a tool for exploring mathematical concepts, visualizing and analyzing data, and developing problem-solving skills [12]. GeoGebra also provides a platform for sharing and collaborating on math content, such as lessons, activities, and assessments. A device that can be clouded in the GeoGebra-assisted learning process is Edmodo. Edmodo is a web-based platform and mobile application that makes it accessible to users on various devices [13], [14]. Edmodo is also integrated with other educational tools like Google Drive, Microsoft Office, and Turnitin. Overall, Edmodo and GeoGebra are valuable tools for educators and potential students to connect and collaborate in blended learning. Blended learning is an educational approach combining traditional classroom instruction with digital and internet-based educational resources.

Teaching materials and computer-assisted learning processes, such as GeoGebra, have proven effective in strengthening the learning and understanding of complex mathematical concepts visually [15]. Research findings show that computer-assisted teaching materials, including GeoGebra, can broaden mathematical knowledge and make it easier to explore subject matter [12]. Students can better understand the information presented by incorporating mathematical functions into the software. As a result, students can develop reasoning skills, generalize data, and generate conclusions based on the usefulness of current procedures. Researchers propose using Edmodo to improve learning in the blended learning [16]. This software can be easily accessed and used on mobile phones or computers, making it more convenient and exciting for students to study continuously.

Additionally, researchers will test the efficacy of employing software to learn antiderivative integral and indefinite integral content while using calculus to solve problems. More research is needed on the application of technology in mathematics education, particularly regarding enhancing problem-solving abilities. One area that has yet to receive attention (state of the art) in learning mathematics is the Fusion Edmodo and GeoGebra as supporters of blended learning.

This study aimed to investigate the effectiveness of problem-based mathematics learning through blended learning with the help of Edmodo and GeoGebra in improving problem-solving skills in mathematics learning. The formulation of the problems discussed in this study are:

i) What are the criteria for improving the problem-solving ability of students who learn with blended learning using Edmodo and GeoGebra (BL-UEG) and blended learning using Edmodo without GeoGebra (BL-EWG)?
ii) Is there a discernible difference between BL-UEG and BL-EWG in how they affect the development of problem-solving abilities?
iii) Can the increase in problem-solving abilities be distinguished between students who use BL-UEG and those who use BL-EWG as a tool in learning mathematics?

2. METHOD

2.1. Research design

This study used a quantitative approach and a quasi-experimental pre-test and post-test control group design [17]. The learning model is the research's independent variable while problem-solving aptitude

is the dependent variable. The experimental group used BL-UEG, whereas the control group used BL-EWG. The purpose of giving the pre- and post-test is to assess the increase in problem-solving skills in both groups.

To conduct research, the researcher first explained the features and capabilities of Edmodo and GeoGebra. Blended learning is then utilized, blending in-class and out-of-class learning using the Edmodo and GeoGebra programs and distributing learning materials such as materials, videos, assignments, and exam results. According to the field studies [17]–[19], this tool was selected because it is well-known to students and can facilitate organization and communication while studying.

2.2. Sample

This research was conducted at one of the private universities in Banten-Indonesia, namely Universitas Bina Bangsa. The mathematics code for calculus is KOM141215 (3 credits) for 2nd semester. The fact that this research was conducted at a university makes it difficult to randomize each course and apply it to control and experimental groups. One effective method is to use a quasi-quantitative experimental study [16], which allows control over certain factors that can result in a flawed experiment [20]. The research process does not create new groups of students but rather uses existing groups to identify experience groups and control groups with similar characteristics. This research involved 72 two-semester students at a private university in Banten, Indonesia, with details of 36 students in the experimental class (11 male and 25 female) and 36 students in the control class (10 male and 26 female). Research participants were selected through purposive sampling, where two classes with the same abilities were selected. Verification of the similarity of abilities was carried out using an independent t-test, yielding $t(72)=0.68$ and $p>0.05$, showing that the experimental and control classes' skills were on par. A balanced distribution of skills is significant to ensure that the treatment of the learning model and tools used increase problem-solving abilities.

2.3. Instrument

At the data collection stage, the test instrument was designed to measure students' problem-solving abilities. This test consists of five essay questions focused on evaluating problem-solving skills, including the development and application of problem-solving strategies, as well as reflection on the process [21]. Before implementation, the validity and reliability of this test instrument were checked through a series of tests.

The validity and reliability of the instrument are the main focus of attention in this research. A series of tests were conducted to measure the instrument's validity, including a content validity test involving assessments from experts in the related field. Experts provide input on the questions in the questionnaire to ensure the instrument's suitability to the research objectives and the accuracy of measuring the variables of interest. In addition, test validity is assessed using two approaches, namely content validity and empirical validity.

The assessment of the content validity of the instrument involved mathematics education experts. The instrument passed the content validity test, indicating that the instrument met the research objectives. For empirical validity, product-moment statistical correlation analysis is used. The trial was conducted on 30 students who had previously studied the volume integral of rotating objects. Empirical validity is assessed by comparing student exam results with the average daily exam results of the previous semester. The results show that the problem-solving ability test is considered valid, with an instrument validity coefficient of 0.455, more significant than the benchmark of 0.361.

The problem-solving ability test instrument used in the research has undergone a series of validity and reliability tests to ensure the reliability and validity of the data collected. Reliability testing was carried out using the retest method, where the questionnaire was distributed to respondents at two different times to check the consistency of the answers. Cronbach's alpha coefficient was also applied to measure the internal consistency of questions in the instrument. The reliability test results show a moderate reliability category, with a Cronbach's alpha score of 0.485. Thus, this test instrument is considered valid and reliable for measuring students' problem-solving abilities in this research.

Several steps were implemented during the design and implementation of the study as control measures for confounding variables. One method of control is the selection of a control group that is comparable to the experimental group. Statistical analysis, such as analysis of covariance, is also applied to control confounding variables during the data analysis process. This approach aims to ensure that differences in results between the experimental and control groups can be explicitly attributed to the treatment given and not caused by external factors that might influence the research results.

It should be noted that this research has received ethical approval from the university in Banten. This approval ensures that research is conducted per ethical standards, including protecting participants' rights and welfare. Data validity management is carried out carefully through detailed data collection, processing and analysis stages, taking into account the procedures and measuring tools used.

2.4. Research procedure

The research procedure was carried out in two stages: preparation and implementation. Field and literature studies were conducted better to understand the research problem during the preparatory stage. Validity and reliability were confirmed in the research instrument using content and empirical validity methods.

First, experts with problem-solving skills evaluate the ability of the instrument to measure problem-solving abilities. Based on their feedback, necessary adjustments were made to the instrument, and it was evaluated on pupils who were not involved in the study. Then, empirical validity and reliability were evaluated using statistical analysis. The instrument is prepared for research once it has been deemed valid and dependable.

The second is the implementation stage, where the researchers select study participants, and the management of research permits are handed over to the relevant parties. Participants were selected based on observation, and a pre-test in learning was given before treatment. The post-test was then carried out after the calculus learning process's conclusion in the rotating material volume.

2.5. Data analysis

Normality and homogeneity assessments were made before using quantitative statistical tests. The Kolmogorov-Smirnov test was used to gauge normality and Levene's to calculate homogeneity. The increase in students' problem-solving skills in both groups was measured using normalized N-Gain as (1) [21], [22].

$$Normalized\ Gain\ (g) = \frac{Posttest\ score - Pretest\ score}{Ideal\ maximum\ score - Pretest\ score} \quad (1)$$

The normalized gain score interpretation criteria and requirements are described in Table 1. This study involved descriptive and hypothetical research questions. For descriptive research questions, a descriptive statistical analysis such as mean, standard deviation, and skewness was used to explain the development of problem-solving abilities in both classes. The standards for enhancing problem-solving skills in both groups are shown in Table 1, and hypothesis testing was used to address the second and third study objectives. Paired-sample t-tests and independent t-tests were also used. The pre-test, post-test, and N-Gain data were first tested for normality and homogeneity. The data were then examined using the statistical techniques of the paired sample t-test and the independent t-test [21], [23].

Table 1. Interpretation of the criteria, normalized gain score

Gain score	Interpretation
g≥0.7	High
0.30≤g<0.70	Medium
g<0.30	Low

3. RESULTS AND DISCUSSION

This study's primary goal is to compare how well BL-UEG and BL-EWG work to improve students' problem-solving skills. Three study subjects have been created by comparing the effectiveness of BL-UEG and BL-EWG. The following section describes a descriptive model of the statistical analysis results used to improve students' problem-solving abilities. The first research question has been found and discussed through descriptive statistical analysis, and the findings are presented in Table 2.

Table 2 provides a descriptive statistical analysis of improving students' problem-solving abilities using BL-UEG and BL-EWG. The research findings showed that students who used BL-UEG showed a more significant improvement in problem-solving skills (mean N-Gain=0.67) than those who used BL-EWG (mean N-Gain=0.56). Both classes demonstrate improvement criteria that fall into the medium category. The distribution of improvement data on BL-UEG (s=0.26) is more diverse than that of BL-EWG (s=0.15). Both classes got a negative skewness score, which shows that the graph of increasing problem-solving skills tends to be negative. This trend indicates that the scores for enhancing problem-solving skills focus on high scores.

Table 2. Descriptive problem-solving ability improvement based on the model

Model	N-Gain		
	Mean	Std. Deviation	Skewness
BL-UEG	0.67	0.26	-0.29
BL-EWG	0.56	0.15	-0.16

Before statistical analysis, we tested the data from both classes, including the pre-test, post-test, and N-Gain values, for normality and homogeneity. The results of the normality test for both types are shown in Table 3. Before doing the paired-sample t-test and paired-sample t-test, the normality test results from the Kolmogorov-Smirnov test for each problem-solving skill score from the two classes are shown. The t-test independently answered the second and third research questions.

Table 3 displays the outcomes of the Kolmogorov-Smirnov test (Sig.), which was performed on the pre-test, post-test, and N-Gain scores for both groups. The findings show that the data has a normal distribution because the Kolmogorov-Smirnov (Sig.) score for the three scores in both classes surpasses 0.05. Thus, both groups' pre-test, post-test, and N-Gain scores were from populations with normal distributions. Table 4 displays the results of the Levene test, which was used to determine the homogeneity of the data.

Table 3. Results of the normalcy test

Model	Test	Kolmogorov-Smirnov test[a]		
		Statistic	df	Sig.
BL-UEG	Pre-test	0.132	36	0.064
	Post-test	0.134	36	0.067
	N-Gain	0.143	36	0.200*
BL-EWG	Pre-test	0.141	36	0.076
	Post-test	0.143	36	0.078
	N-Gain	0.074	36	0.200*

Table 4. Test the homogeneity of data in both classes

	Pre-test	Post-test	N-Gain
Levane statistic	0.748	0.164	0.842
df1	1	1	1
df2	70	70	70
Sig.	0.36	0.68	0.45

Table 4 shows significant values for pre-test, post-test, and N-Gain scores for both classes that are greater than 0.05, indicating that the variances of these scores are the same. Table 4 demonstrates that the data conforms to the variance homogeneity assumption. Hence, using a t-test is trustworthy. Tables 5-7 display the results of the paired sample t-test from the analysis carried out using the SPSS program.

The findings of pair 1 are shown in Table 6, specifically the comparison of the students studying with BL-UEG problem-solving skills between the pre-test and post-test, which achieved a significant level of 0.001, which is less than α=0.05. As a result, using BL-UEG dramatically impacts how well students learn to solve problems. Table 7 shows the relationship between the pre-test and post-test results. A correlation value of 0.542 was obtained for pair 1 with a significance level of 0.001, which is substantially lower than 0.05, indicating a substantial positive link between the students who had taken BL-UEG courses before and after the test.

Table 5. Paired samples statistics

	Pair 1		Pair 2	
	Pre BL-UEG	Post_ BL-UEG	Pre BL-EWG	Post BL-EWG
Mean	25.6812	74.6716	33.4287	68.6132
N	36	36	36	36
SD	13.40376	13.13747	11.46782	12.60747
SE. Mean	2.33784	2.11253	1.82785	2.23543

Table 6. The t-test on paired samples for both classes

	Pair 1	Pair 2
	Pre_BL-UEG-Post_BL-UEG	Pre_BL-EWG-Post_BL-EWG
Mean	−47.12480	−35.37674
SD	13.12627	8.34215
t	−20.734	−21.767
df	36	36
Sig.	0.001	0.008

Table 7. Paired sample correlations

	Pair 1 Pre_BL-UEG & Post_BL-UEG	Pair 2 Pre_ BL-EWG & Post_BL-EWG
N	36	36
Correlation	0.542	0.714
Sig.	0.001	0.003

The analysis's findings from Table 6 also demonstrate pair 2, which compares the students who study with BL-EWG problem-solving skills pretest-posttest, as having a significant level of 0.008, less than α=0.05. As a result, using BL-EWG dramatically impacts how well pupils learn to solve problems. In contrast, results for pair 2 in Table 7 revealed a correlation score of 0.714 and a significant level of 0.00, which is substantially lower than 0.05, indicating a strong positive link between the students who studied BL-EWG problem-solving techniques before and after the test. The independent t-test is used in the following analysis to evaluate hypotheses about differences between students who study with BL-UEG and students who study with BL-EWG in enhancing problem-solving abilities as shown in Table 8.

The test findings from Table 8 indicate that t (70)=2.86 with a significant level (Sig. (2-tailed)) of 0.003 is much lower than 0.05. As a result, there is a significant difference between the improvement in problem-solving abilities of students studying with BL-UEG and those studying with BL-EWG. Table 2 demonstrates that students who studied with BL-UEG saw a problem-solving ability increase of 0.67, which was higher than the 0.56 rise in students who studied with BL-EWG regarding problem-solving ability.

Blended learning in the fusion of Edmodo and GeoGebra allows students and lecturers to communicate remotely through various methods. Blended learning eliminates the need for physical class meetings or extra class time. Several applications are required to support the blended learning process by offering unique advantages. The Edmodo application provides PPT, PDF content, and learning videos, while the device is a GeoGebra tool to solve problems regarding the integral volume of rotating objects as presented in Figure 1.

Table 8. N-Gain comparison test for both classes

	Levene's test for equality of variances		t-test for equality of means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	0.734	0.253	2.86	70	0.003
Equal variances not assumed			2.77	70	0.004

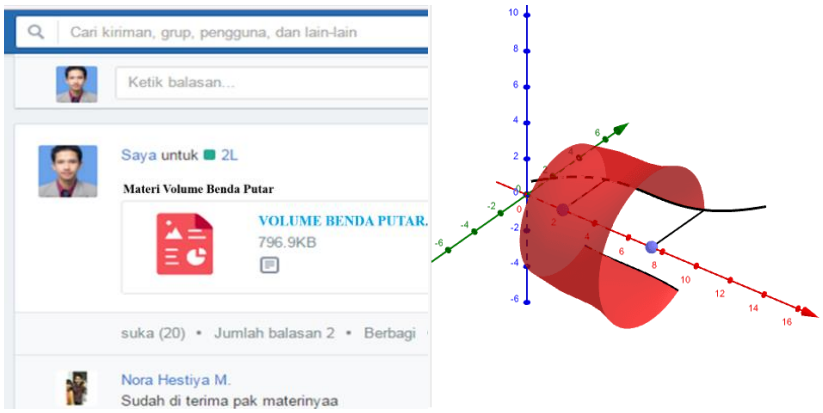

Figure 1. Learning videos: blended learning in the fusion of Edmodo and GeoGebra

The GeoGebra tool supports many representations of mathematical concepts, including algebraic, visual, and numerical spreadsheet representations. Using GeoGebra does not require programming and allows students to help solve problems about volume integrals of rotating objects from various perspectives. Blended learning in the fusion of Edmodo and GeoGebra, all of these interactions occur, which can motivate students when there is not enough time in class. The Edmodo learning application offers interaction between students and lecturers as shown in Figure 1.

After conducting a descriptive analysis (Table 2), it was found that there was an increase (moderate category) in students' problem-solving skills in the BL-UEG and BL-EWG learning classes. The learning model has characteristics that support the learning process. For example, the GeoGebra tool was uploaded in Edmodo to help and support solving problems about the integral volume of rotating objects. In addition, Table 5 presents the analysis results showing differences in the development of problem-solving skills between students who underwent the BL-UEG and BL-EWG models. In the BL-UEG and BL-EWG classes, Table 7 shows a substantial positive association between students' pre-test and post-test problem-solving skills. BL-UEG can be seen in the learning process, and students actively discuss the material as shown in Figures 1 and 2.

Improving problem-solving abilities can be achieved by teaching students how to communicate their ideas effectively. It is important to note that problem-solving skills can also be observed through the learning process and the delivery of students' ideas. This learning process aligns with social cognitive theory, which states that learning can occur only by observing others [21].

Based on the analysis presented in Table 5, the use of BL-UEG significantly improves students' problem-solving skills compared to learning BL-EWG. The application of BL-UEG effectively teaches mathematics. BL-UEG enables remote communication and provides a positive learning experience for students to discuss problem-solving. GeoGebra-assisted learning videos improve problem-solving skills [24], [25]. In addition, online quizzes using Edmodo are convenient and flexible because they can be done anywhere and anytime [26]–[28]. Previous research results also stated that using GeoGebra encourages frequent problem-solving and communication skills among students [29]. The learning process and the Quiz on the Application of BL-UEG are illustrated in Figures 2 and 3.

The environment of the integrated learning process with Edmodo and GeoGebra is shown in Figure 2. Here, the two platforms work together to establish a comprehensive learning environment. Students can use interactive learning tools like GeoGebra to investigate mathematical ideas through practical applications. Meanwhile, Edmodo serves as a virtual forum where students can interact, communicate, and access course materials in a planned way. The picture shows an attempt to build a prosperous and integrated learning experience in a blended learning method by combining these two platforms.

Figure 2. The atmosphere of the blended learning process uses Edmodo and GeoGebra

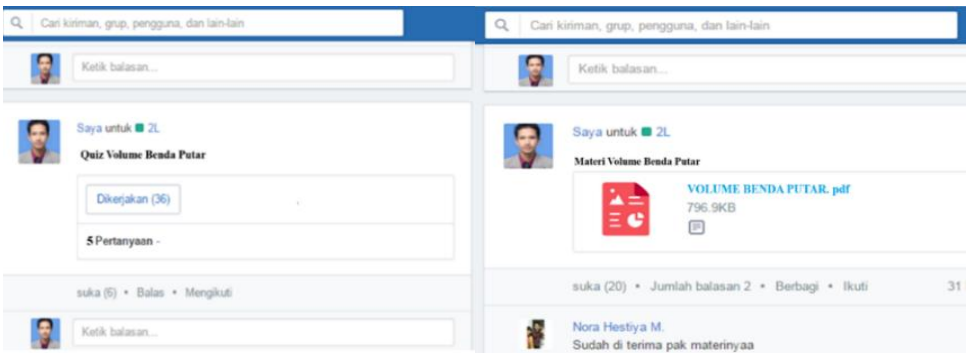

Figure 3. Display the material and quiz results on the Edmodo application

Figure 3 shows the appearance of materials and test scores in the Edmodo application. Here, Edmodo is an online learning platform that makes quizzes and presentation of teaching materials easier. Apart from quiz results that reveal information about student success, the figure also displays a clear and comprehensive presentation of teaching materials. Figure 3 helps teachers monitor student progress and provide relevant comments by summarizing students' understanding of the lesson material.

Increased mathematical problem-solving abilities can be associated with different learning activities and environments in the BL-UEG and BL-EWG classes. GeoGebra Software in the BL-UEG class provides students with a more exciting and comprehensive learning experience, resulting in better problem-solving skills. The GeoGebra research states that mathematical abilities can improve reasoning and problem-solving skills [30]. On the other hand, learning in the control class uses something different than Edmodo and GeoGebra, which limits students' opportunities to explore their ideas and results in more rigid thinking. To improve problem-solving skills, Pólya [4] suggests four steps: understanding the problem, planning solutions, implementing plans, and reflecting. Teachers, colleagues, or teaching materials can serve as models for problem-solving behavior. The use of attractive and motivating models, such as those presented in Edmodo and GeoGebra, can help students focus on the process of learning mathematics. By observing the behavior of the learning process displayed during the problem-solving process, students can absorb and consider the cognitive factors that play a role in the problem-solving [4].

The increase in problem-solving abilities between students who study with BL-UEG and BL-EWG is significantly different, as shown in Table 8. BL-UEG proves to be more effective in enhancing students' problem-solving skills than BL-EWG. These findings support previous research that showed the effectiveness of Edmodo learning in the blended learning field [27]. The use of a problem-based learning model with BL-UEG significantly improves problem-solving abilities, resulting in good features for the average value of problem-solving skills, consistent with previous research fields [29], [30]. Although the difficulties students may encounter are tied to resources and other circumstances, this research positively impacts the advancement of learning technologies and the learning environment for students [25].

The 21st century's leading resource for lifelong learning has been recognized as the blended learning approach combining Edmodo and GeoGebra. However, student psychological issues might impede learning, particularly in terms of readiness for learning. GeoGebra can assist lecturers and students in solving math problems more quickly so that students are inspired to concentrate on studying in these circumstances. Teachers must also set an excellent example for their students and use various teaching techniques to keep them interested in their lessons. Students can stay focused and engaged by using additional resources and apps. The results of this study have consequences for lecturers who want to encourage students to solve problems as they learn mathematics.

4. CONCLUSION

The results showed that the increase in problem-solving abilities in both classes was in the medium category. Problem-based mathematics learning through BL-UEG and BL-EWG significantly impacted students' problem-solving abilities. Specifically, the BL-UEG group showed significantly more improvement than the BL-EWG group. However, this research only included two-semester university in Banten students who took calculus courses on volumes of rotating objects. Further research is required to examine other components of mathematical ability because this study's measuring of mathematical aptitude is restricted to problem-solving skills. Additionally, there is a need for further exploration and development of alternative blended learning models to address the limitations identified in this study.

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BIOGRAPHIES OF AUTHORS

Anton Nasrullah is a Mathematics Educator at Universitas Bina Bangsa (UNIBA). He is passionate about improving the quality of student teaching, learning, and development in a higher education environment. His current research interests lie in prospective mathematics teacher education, mathematical literacy, learning using educational technology, learning media, STEAM learning, classroom action research, didactical design research and 21st-century learning. He can be contacted at: anton.nasrullah@binabangsa.ac.id.

Mimih Aminah holds a doctor's degree in education from the Universitas Pendidikan Indonesia. With over 30 years of teaching experience, she has served as a lecturer at the Mathematics Education Program, Faculty of Education and Teacher Training, Universitas Sebelas April, Indonesia. Her current research interests primarily focus on the mathematical thinking process and mathematics education at the elementary and secondary school and university levels. She is particularly interested in exploring students' learning and development in various areas of education. She can be contacted at email: mimih_fkip@unsap.ac.id.

Umalihayati holds Doctor of Education Management degree, a degree in education from Universitas Pakuan Bogor, Indonesia. She has more than 20 years of experience as an academic starting from the Aisyiyah Banten Midwifery Academy and the Aisyiyah Banten Health Polytechnic. Now active as a permanent lecturer and structurally as Head of Quality Assurance Group at Bina Bangsa University. Her current research interests include learning technology and education management. Her current research topic is in the field of education learning and management. She can be contacted at email: umalihayati@binabangsa.ac.id.

Kurniati Rahmadani is a lecturer in information technology education at Universitas Bina Bangsa (UNIBA). She was appointed as a lecturer at the university in 2022 and after completing postgraduate studies in the informatics engineering education department at Universitas Negeri Padang. She is passionate about improving the quality of teaching and student learning and their development in schools and in higher education settings. Her publication topics including education, learning, teaching, and learning media in the 21st century. She can be contacted at email: kurniatirahmadhani@gmail.com.

Sri Adi Widodo is an Associate Professor and lecture at the Universitas Sarjanawiyata Tamansiswa, Yogyakarta. His research focuses on mathematics education, media of learning, learning and teaching in mathematics, sociomathematics norm, and single subject in mathematics education. He can be contacted at email: sriadi@ustjogja.ac.id.

Mohamad Husni is a lecturer at Bina Bangsa University (UNIBA), Indonesia. His researches focus on accounting and auditing. He can be contacted at email: mohamadhusnni06@gmail.com.