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https://doi.org/10.55463/issn.1674-2974.50.2.6

How Can Blended Learning and GeoGebra Promote Students’ Achievement in Calculus during the COVID-19 Pandemic?

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Received: December 6, 2022 • Review: January 2, 2023 • Accepted: February 11, 2023 • Published: February 27, 2023

Abstract: Calculus is one of the most important courses to take, especially for those studying science and engineering because it can help them understand concepts and formulas in these fields. The COVID-19 pandemic impacts learning in universities globally. Observations from three colleges in West Sumatera (Padang State University, Andalas University, and Padang State Polytechnic) revealed that during the COVID-19 pandemic, students’ achievement was unsatisfactory due to entirely online calculus lectures. The study’s main goal was to see how blended learning and GeoGebra-based Calculus courses affected student achievement in online learning. The population of this study consisted of 224 undergraduate students from Andalas University who were enrolled in Calculus courses in the 2021 academic year's odd semesters, divided into four classes: A1, A2, A3, and A4, whereas the research sample consisted of two classes (A1 and A4) with 114 students randomly selected. Lectures were held seven times in the experiment and control classes, using blended learning and GeoGebra aid in the experiment class and fully online learning in the control class. A four-question midterm test was employed in this study as an instrument. The test is based on the learning objectives of the calculus course and has been declared valid by experts in mathematics and mathematics education. The findings show that using blended learning and GeoGebra to teach and learn calculus positively impacts achievement. More student collaboration, more student-centered knowledge growth and engagement, more flexibility in learning and teaching, and a well-balanced array of learning resources and methodologies are all benefits of blended learning and GeoGebra. A significant difference was in calculus achievement between male and female students, and there was no interaction between gender and learning factors toward calculus achievement in online learning.

Keywords: blended learning, calculus achievement, COVID-19 pandemic, gender, GeoGebra.

混合学习和地理坐标如何在新冠肺炎大流行期间促进学生的微积分成绩？

摘要：微积分是最重要的课程之一，尤其是对于那些学习科学和工程的人来说，因为它可以帮助他们理解这些领域的概念和公式。新冠肺炎流行影响全球大学的学习。西苏门答腊三所大学（Padang State University, Andalas University, and Padang State Polytechnic）的观察显示，在新冠肺炎大流行期间，由于完全在线微积分讲座，学生的成绩并不理想。该研究的主要目标是了解混合学习和基于新冠肺炎的微积分课程如何影响学生在线学习的成绩。本研究的人群包括来自安
1. Introduction

Calculus is an area of mathematics with numerous applications in science and technology, making it extremely important to master. Functions, rates of change, limit, continuity, derivative, slope, integral, and differential equations are among the essential topics in calculus [1–6]. According to [2], the concept of limit is the most fundamental notion. This is because of its relationship with several other essential ideas in calculus, such as derivatives, integrals, and continuity. The concept of slope is commonly used in science, such as physics and chemistry, to explain the velocity of an object traveling with constant acceleration, the ideal gas law, and the Arrhenius equation [4]. Meanwhile, calculus principles such as piecewise linear, quadratic, cubic, exponential, sine, cosine, linear, and polynomial functions; rates of change, derivative, and integral are commonly employed in engineering [7]. As a result, calculus material must cover all of these essential topics, with the amount of detail and applicability tailored to the needs of each science and engineering department.

Until early March 2020, calculus lectures at most colleges, especially in West Sumatera, were held face-to-face but suddenly switched to online learning because of the coronavirus disease. Coronavirus disease, known as COVID-19 by the WHO, has been designated a world pandemic [8]. Today, COVID-19 has spread worldwide and has affected our lives, including education [9, 10]. This pandemic necessitates a massive learning model policy, and the epidemic is a severe problem for the educational system [11]. All of us should keep lectures in the pandemic period well while keeping COVID-19 from spreading more widely. E-Learning or online learning is a wise choice for courses during the pandemic [12]. This is possible because universities in Indonesia are supported with internet infrastructure.

Following up on the COVID-19 pandemic, the Government of Indonesia, in this case, the Ministry of Education, Culture, Research, and Technology, gave instructions to universities so that face-to-face lectures are directly eliminated and replaced with lectures by using the internet or online learning networks. Many forms of online learning platforms can be used to achieve learning objectives, for example, WhatsApp [13], live-video conferencing [14], and E-Learning prepared by the university through the campus website [15]. Given the absence of guarantees that pandemics such as COVID-19 and the like will not happen again, E-learning-based lectures will remain the top choice in the future [16].

The experiences of authors who carried out online learning at Padang State University, Andalas University, and Padang State Polytechnic during the COVID-19 pandemic, where lectures are completely delivered online through the university learning management system, most students who learn through online learning struggle hard to master each material, but they have difficulty mastering it well, as happened in calculus learning. This hinders the achievement of learning objectives, especially those concerning the mastery of the material by students. This is evidenced by the final calculus exam of Andalas University students’ average of 50.45, which is much lower than the average before the COVID-19 pandemic. Many researchers have report that most students have trouble grasping calculus in offline learning. Among the topics that students find challenging were: limits [17–19], derivatives [5, 20–22], functions [1, 3], rate of change [23–25], and integral [4, 26, 27]. They then proposed various learning strategies to address this, such as the cognitive orientation of calculus tasks [28], multirepresentations of mathematics concepts (Hoban, 2018), formal definition preceded by an informal definition [19], and using diagrams to represent relationships between quantities [5].

What factors contribute to low-calculus academic accomplishment at Andalas University, particularly during the COVID-19 pandemic? Based on an interview with ten students who received the lowest
grade on the final exams, it was discovered that: 1) the presentation of mathematical concepts and theorems is challenging to understand; 2) there are insufficient examples related to mathematical concepts (example and counter-example); 3) there are bad examples related to the use of theorem; 4) Even if it has been read many times, some mathematical principles are difficult to grasp; 5) Students do not know how to check the accuracy of the assignment answers; 6) Students have trouble approaching colleagues and lecturers for assistance; 7) College assignments are excessive, causing time to be spent on tasks rather than understanding lecture content; 8) Inadequate examples of calculus application in daily life, particularly in modeling mathematical problem into mathematical equations.

The interview results revealed two main problems in calculus learning that is entirely online through the website (without any face-to-face, both offline or online). First, there are several concepts and theorems in calculus that are difficult for students to understand without the help of explanations from lecturers. Second, Students have difficulty checking the correctness of the answers to the tasks performed by the students. Because offline learning is not possible during the COVID-19 epidemic, to tackle the first problem, lecturers can use blended learning-based calculus learning. Namely, website-based lectures accompanied by face-to-face online through Zoom meeting applications, and lecturers can use GeoGebra math applications to visualize concepts and theorems in calculus and can be used by students to check the correctness of the answers to tasks they create, which are two up-and-coming solutions to try. GeoGebra offers plenty more applets for calculus lectures compared to other math applications.

Instructional methods incorporating offline and online learning have been termed blended learning (BL) [29]. It is a chance to combine technical advancements and innovations delivered through online learning with the engagement and participation given by the best traditional education [30, 31]. The benefits of BL include: instructors and students communicating more effectively, increased student collaboration effectiveness, increased student-centered knowledge development and engagement, increased learning and teaching flexibility, and a well-balanced mix of learning tools and approaches [32, 33]. BL has a more favorable effect than completely online or traditional face-to-face situations [34], including enhanced learning results and attitudes toward mathematics (statistics) [35]. As a result, BL holds a lot of promise for teaching calculus during the COVID-19 pandemic. Unfortunately, the use of BL necessitates significant support for information and communication technology (ICT).

ICT has become one of the most significant factors for improving teaching and learning [36, 37], with mathematics teaching and learning being the most important [38]. As a result, to perform effectively in modern technology-driven schools, students are expected to gain various skills [39], and the use of ICT in learning give the opportunity for students to explore their previous knowledge related to the topics they are studying [40]. GeoGebra, as an ICT tool, is one of the most recent instructional tools that have piqued the interest of researchers and math educators due to its potential to transform mathematics teaching and learning [41], from primary school to university level [42]. It promotes mathematical experiments and discoveries both in the classroom and at home and can be used for active and problem-oriented instruction [43]. It is free software [44] with various GeoGebra applets accessible at www. Geogebra. Org. Millions of people communicate daily, whether online or offline [45], and this can help pupils enhance their mathematical thinking [46–48]. Given the benefits of using GeoGebra in mathematics learning, especially to visualize concepts in calculus, combining BL with GeoGebra will make it easier for lecturers to teach and students to learn calculus. However, due to the disparities in attitudes between female and male students concerning using ICT in the classroom, we must ensure that GeoGebra is beneficial to all students.

Gender differences in mathematics achievement and attitudes have been widely researched. Girls do poorly in mathematics than males in face-to-face learning or offline learning and have more unfavorable attitudes toward mathematics [49, 50]. Because blended learning requires the use of computers, men are more likely than women to use ICT in their learning [51]. Some differences are observed in e-learning among men and women [52]. This study answers the following research question: (1) Are students who learn calculus through blended learning more successful than those who learn entirely online? (2) Is there a difference in calculus achievement between males and females? (3) Is there an interaction between gender and learning factors toward calculus achievement?

2. Methods

This type of research design was pseudo-experimental research using a posttest-only control group design. The population of this study consisted of 224 undergraduate students from Andalas University who were enrolled in calculus courses in the 2021 academic year’s odd semesters, divided into four classes: A1, A2, A3, and A4, whereas the research sample consisted of two classes with 114 students randomly selected, namely class A1 as an experimental class and class A4 as a control class.

The experimental class used blended learning and GeoGebra, with three times as much asynchronous fully online learning and four times as much face-to-
face learning via the Zoom Meeting platform, compared to seven times as much asynchronous, fully online learning in the control class, both classes using the same teaching materials and being taught by the same of lecturer. However, in the experimental class, lectures were enriched using GeoGebra to visualize concepts and properties in calculus and to check the correctness of students’ solutions in solving exercises in face-to-face learning via the Zoom Meeting platform. For example, when explaining how to create a graph of a function, the lecturer first discusses how to draw a graph function in the following manner. First, get the coordinates of a few points that satisfy the equation and write them down in a table. Plot these points on a Cartesian coordinate in the second step. Connect the points with a smooth curve in the third step. Furthermore, lecturers and students use the process to draw a function graph; moreover, the graph of the function is compared to the chart created using the GeoGebra software. At Andalas University, asynchronous, fully online calculus courses are delivered using “ilearn,” a Moodle-based learning platform that enables educators to arrange teaching materials and provide online lessons. Lecturers can also create student-centered activities such as questionnaires, forums, and assessments, which can be scored online when students take quizzes, midterms, and finals.

The instrument used in this study was a four-question midterm test, as presented in Table 1. The test is based on the learning objectives of calculus courses and has been declared valid by experts in mathematics and mathematics education. Based on the truth level of the answer, each student’s answer is given a score of 0, 1, 2, 3, or 4. The Midterms in both classes were held at the eighth meeting.

Table 1 The four-question midterm test for calculus

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Solve the inequality $</td>
</tr>
<tr>
<td>2.</td>
<td>Given $f(x) = \begin{cases} x^2, &amp; x &lt; 2 \ -x, &amp; x \geq 2 \end{cases}$, sketch the graphs of $f + g$</td>
</tr>
<tr>
<td>3.</td>
<td>Given $f(x) = \sqrt{1 - x^2}$, find the limit as $h \to 0$ of $\frac{f(x+h) - f(x)}{h}$</td>
</tr>
<tr>
<td>4.</td>
<td>Given $f(x) = \begin{cases} ax + b, &amp; x &lt; 3 \ -x^2 + 1, &amp; x \geq 3 \end{cases}$, find $a$ and $b$ so that $f(x)$ at 1 and 3</td>
</tr>
</tbody>
</table>

The first, second, and third research questions were answered using Analysis of Variance (ANOVA) using SPSS 17.0 at a significant level of 5%, followed by a normality and homogeneity test.

3. Results and Discussion

Data on students’ achievement in calculus were obtained from the midterms of the courses, as shown in Tables 2 and 3.

Table 2 The descriptive statistics of students’ calculus achievement in the experiment and control

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Students</th>
<th>Mean</th>
<th>Stand. Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>60</td>
<td>66.9167</td>
<td>13.34330</td>
</tr>
<tr>
<td>Control</td>
<td>54</td>
<td>60.4630</td>
<td>13.29167</td>
</tr>
</tbody>
</table>

Table 3 Male and female students’ calculus achievement descriptive statistics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number of Students</th>
<th>Mean</th>
<th>Stand. Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>33</td>
<td>68.1818</td>
<td>10.73969</td>
</tr>
<tr>
<td>Female</td>
<td>81</td>
<td>62.0988</td>
<td>14.35845</td>
</tr>
</tbody>
</table>

Table 2 shows that the average calculus achievement for the experimental class was higher than the control class (66.9167 > 60.4630), but his performance was less evenly distributed (13.34330 > 13.29167). Table 3 shows that the average calculus achievement for male students was higher than that for female students (68.1818 > 62.0988), and their performance is evenly distributed (10.73969 < 14.35845).

To determine if the difference shown in Table 2 and Table 3 is significant, an ANOVA was performed by first performing a test of normality and homogeneity, as presented in Tables 4 and 5.

Table 4 Normality test with Shapiro-Wilk for students’ achievement in calculus

<table>
<thead>
<tr>
<th>Class</th>
<th>K-S Statistic</th>
<th>df</th>
<th>Sig.</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>.978</td>
<td>60</td>
<td>.365</td>
<td>The score was normal (.365 &gt; 0.05)</td>
</tr>
<tr>
<td>Control</td>
<td>.964</td>
<td>54</td>
<td>.100</td>
<td>The score was normal (.100 &gt; 0.05)</td>
</tr>
</tbody>
</table>

Table 5 The homogeneity of variance Levene’s test for experiment and control class

<table>
<thead>
<tr>
<th>Levene-statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>.000</td>
<td>1</td>
<td>112</td>
<td>.991</td>
<td>The variance score was equal (.991 &gt; 0.05)</td>
</tr>
</tbody>
</table>

Since both data groups have a normal distribution and homogeneous variance, an ANOVA was performed. Table 6 summarizes the findings.

Table 6 ANOVA results summary for students’ achievement in calculus

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>.045</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>646.399</td>
<td>1</td>
<td>646.399</td>
<td>3.761</td>
<td>.045</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>867.120</td>
<td>1</td>
<td>867.120</td>
<td>5.046</td>
<td>.027</td>
<td></td>
</tr>
<tr>
<td>Method * Gender</td>
<td>144.384</td>
<td>1</td>
<td>144.384</td>
<td>.840</td>
<td>.361</td>
<td></td>
</tr>
<tr>
<td>Gender Error</td>
<td>18904.380</td>
<td>110</td>
<td>171.858</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>485950.000</td>
<td>114</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is a significant difference between the experimental and control classes, as seen in Table 6 (.045 < 5%), likewise with males and females (0.027 < 5%) in calculus performance. However, there is no interaction between gender and learning factors toward
calculus achievement (.361 > 5%).

This research implies an expanding corpus of research on undergraduate student accomplishment by examining the impact of blended learning and GeoGebra in online learning on students’ calculus achievement. Why blended learning and GeoGebra can promote student achievement in online learning? Students are more engaged in constructing their knowledge in blended learning than offline learning. They receive guidance in building their expertise from lecturers face-to-face via a Zoom Meeting. Finally, the usage of GeoGebra, particularly Calculus Applets, in teaching and learning Calculus makes lecturers and students can learn and teach calculus more easily.

Experts in the literature suggest at least five points to help students understand calculus: 1) According to [53], mathematical concepts should be represented in multiple representations. When possible, use numerical, algebraic, visual, and verbal representations to help students understand the links between different representations and acquire more profound and comprehensive knowledge. A function concept, for example, can be presented as a graphic, table, graph, word problem, or algebraic formula [1]; 2) A constructivist approach to problem-centered learning/active learning appears to be an effective technique to teaching and learn calculus [54]; 3) GeoGebra can help students learn mathematical concepts, reason, construct and explore knowledge, solve issues, and generate new information [55]. It also aids pupils in better visualizing mathematical topics [56]; 4) Before a formal definition of the notion using mathematical symbols, explanations, and visuals using various representations should be provided [6]; 5) Using challenging mathematical activities to assist kids in learning [28, 57]. All five of these points can be addressed through blended learning and GeoGebra-based learning.

Mathematical learning relies heavily on multiple representations, as they aid students in making sense of mathematical tasks and concepts and facilitating their learning process. They aid students in managing and expressing their thoughts, as well as creating mental models of their mathematical ideas; they aid students in comprehending abstract mathematical concepts, and they aid students in analyzing mathematical problems [58–60]. Multiple representation strategies improve mathematical accomplishment, particularly in subdimensions such as verbal problem solving, reading graphs, interpreting graphs, reading tables, interpreting tables, solving equations, and creating equations. [61]. As a result, lecturers should be aware of how to employ various representations when teaching a particular topic in calculus and how to use some teaching tactics compatible with learning processes with many representations. Because of the numerous representations, it will be feasible to satisfy the students’ varying learning preferences. Here is where GeoGebra comes in, assisting in representing mathematical concepts, particularly calculus, in various forms.

Regardless of the topic or style of the information delivery method, student engagement in active learning is critical to effective learning, and active learning can occur in a classroom, blended learning, or fully online setting. However, there are several ways for adopting and implementing active learning in non-face-to-face settings, including well-designed interactions, group work, and creating a collaborative atmosphere that supports and fosters collaborative learning. Active learning should be woven throughout the core components of an online or hybrid course, such as discussions, assignments, and evaluations, to encourage high levels of student participation [62]. Students engaged in blended learning were more motivated to learn [63], which has consequences for student learning outcomes in the cognitive, affective, and psychomotor domains [64]. Compared to fully online learning, the usage of Zoom Meeting in the blended learning setting in online education allows for more successful discussions between students and lecturers.

Why do male students perform better than female students in calculus in online lectures? Different types of ICT in lectures calculus in online learning are especially beneficial for male students since males are more likely than females to use computers and new media in their learning [51].

4. Conclusion

Based on an analysis of students' calculus achievement using ANOVA, the following conclusions can be drawn. (1) Calculus courses based on blended learning and GeoGebra can improve student achievement significantly. (2) There was a significant difference in calculus achievement between male and female students in online learning. (3) In online learning, there was no interaction between gender and learning factors toward calculus achievement.

Blended learning refers to instructional strategies that combine offline and online learning (BL). Here is an opportunity to combine the technical breakthroughs and advancements made possible by online learning with the participation and engagement offered by the very finest traditional education. The advantages of BL include improved communication between teachers and students, improved student collaboration, more student-centered knowledge growth and engagement, increased flexibility in learning and teaching, and a well-balanced selection of learning tools and methodologies. Compared to fully online or conventional face-to-face settings, BL has a stronger positive impact on learning outcomes and attitudes about mathematics. As a result, BL has a lot of potential for using during the COVID-19 pandemic to teach calculus.
References


Syarifuddin et al. How Can Blended Learning and GeoGebra Promote Students’ Achievement in Calculus during the COVID-19 Pandemic?, Vol. 50 No. 2 February 2023


参考文献:


[9] ALAMYAN P., and ZHANG L. 学生在工程教育杂志 中的工程应用。国际工程教育杂志


[56] OKTAVIYANTHI R., 和 SUPRIANI Y. 在数学和
习微积分中利用微软数学。数学教育杂志, 2015, 6(1): 第 63-76 页. https://doi.org/10.22342/jme.6.1.1902.63-76


