



EFFECT OF BLENDED LEARNING EDUCATIONAL MODEL ON SECONDARY SCHOOL STUDENTS' MATHEMATICS CONCEPTUAL UNDERSTANDING

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Abstract

The study was conducted to assess the effect of a blended learning educational model on grade ten students' mathematics conceptual understanding in Ethiopia. A non-equivalent pre-test and post-test quasi-experimental design was employed. Two intact classes from different schools were randomly selected and assigned to experimental ($n=38$) and comparison group ($n=45$). From the previous semester, students' record book revealed that both groups have almost an equivalent mathematics performance. A one-way ANOVA and paired sample t-test were used to analyze the data. Moreover, to check the equivalence of the groups, the same pre-test was developed and administered. The result indicates that both groups were equivalent. The test covers tenth-grade topics relations and functions, polynomial functions, exponential functions, and logarithmic functions. The study shows that students instructed through the blended learning approach surpassed those taught via the conventional method in their comprehension of mathematical concepts. The one-way ANOVA statistical result revealed there is a notable disparity between groups with effect size of $\eta^2 = .269$, which is a large effect size. Moreover, a paired sample t-test shows the experimental group showed a substantial mean difference of 14.327 with a very large effect size ($d=1.016$) when compared with the comparison group. Thus, the study shows that blended learning was more effective in improving mathematical conceptual understanding when compared with a conventional method of teaching. Based on the findings, the researcher recommends blended learning in mathematics education and suggests stakeholders and policymakers incorporate the model into the curriculum.

Keywords: *blended learning, conceptual understanding, educational model, lab rotation model, mathematical concept*

Introduction

In the fast-paced world of today, education is crucial in preparing students for the diverse challenges and opportunities of the 21st century. Conventional teaching methods by themselves are inadequate for developing the skills and competencies required for success in our complex and interconnected society (Almazroa & Alotaibi, 2023). This awareness has sparked a significant shift in educational paradigms, leading to the rise of 21st-century teaching approaches, particularly in mathematics subject conceptual understanding.

In mathematics, conceptual understanding refers to a deep comprehension of mathematical concepts, operations, and relations (Kemdikbud, 2022; Kilpatrick et al., 2001). It goes beyond just knowing how to perform mathematical procedures; it involves understanding why those procedures work and how different mathematical ideas are interconnected. Conceptual understanding in mathematics is about seeing the big picture and understanding the framework within which mathematical procedures operate. It transforms mathematical learning from rote memorization of steps to a meaningful and integrated comprehension of how and why mathematics works. The researchers seek to rigorously evaluate the effect of blended learning (BL) on conceptual understanding of mathematics among Grade 10 students.

One goal of learning mathematics is to understand mathematical concepts, facts, principles, operations, patterns and solve mathematical problems with flexibility, accuracy, efficiency, and precision (Kemdikbud, 2022). Understanding mathematical concepts is crucial, as it equips individuals with the necessary skills to navigate the challenges presented by the industrial revolution (Baiduri, 2019). This understanding is rooted in the belief that conceptual mastery in mathematics enhances problem-solving abilities (Zulkarnain & Budiman, 2019), provides a framework for conceptualization (Suandito, 2017), and fosters the development of new ideas (Hutagalung, 2017).

Furthermore, Tang and Chaw emphasized the advantages of the BL approach for students, particularly its flexibility regarding time, location, and accessibility (Tang & Chaw, 2013). BL can enhance students' motivation by offering a comfortable and flexible approach to time management, accommodating individual learning preferences, and encouraging autonomy. This, in turn, fosters independence and a sense of responsibility in their educational journey (Tuomainen, 2016). Furthermore, it has been argued that when applied independently, BL performs better than both strategies (Mozelius & Hettiarachchi, 2017). Similarly, BL activities create ample chances for teachers and students to exchange feedback and viewpoints (Albhnsawy & Aliweh, 2016).

BL fosters the development of creative and critical thinking among students engaged in lesson planning effectively. Additionally, it promotes student independence in studying outside the conventional classroom setting, facilitating self-learning and continuous feedback without direct teacher intervention. Students can easily track their progress and review their results independently. Consequently, the role of the teacher shifts from merely facilitating to monitoring and assessing learners' progress, empowering them to take charge of their learning journey (Berga et al., 2021). BL, as an educational approach, merges the benefits of classroom interaction with the active learning facilitated by technology in the online environment. It's important to note that the effectiveness of BL doesn't always align with the ratio of in-person to online delivery methods.

Research has highlighted also several challenges associated with the use of BL (Albiladi & Alshareef, 2019; Shand & Farrelly, 2018). There is a lack of widespread support for blended instruction, as some consider the integration of ICT to be excessively time-consuming (Benson et al., 2011). For instance, creating and preparing teaching materials for online platforms often takes more time than conventional face-to-face teaching. Additionally, the hybrid approach is perceived as more demanding in terms of preparation and course management. Ma'arop and Embi (2016) described blended learning as a significant burden, both physically and mentally, due to the extra time required for tasks such as designing course platforms, uploading materials, responding to student queries, and assessing online assignments, which ultimately increases the workload for educators (Alebaikan & Troudi, 2010).

However, according to the Third National Learning Assessment in Ethiopia (MoE, 2017), a high number of students from secondary school performed poorly in mathematics, which is below standards. The findings also revealed that students' understanding of mathematical concepts and reasoning is low. In addition, (Mills, 2016) also indicated that many students failed to understand mathematical concepts. The assessment conducted by the Program for International Student Assessment PISA (2018) also showed that Ethiopian students' conceptual

understanding of mathematics was found to be below the average when compared with other participating countries and particularly performed less in mathematics literacy. Thus, in order to realize the quality of teaching and learning process in mathematics classrooms, an alternative and innovative learning method (such as technology-integrated instructional techniques) must be implemented (Kemdikbud, 2019; MoE, 2020).

In this manner, conventional learning methods by themselves are inadequate and less effective for developing mathematical competencies among learners (Almazroa & Alotaibi, 2023). To this effect, different researchers indicated that the BL model is an innovative approach that offers an alternative approach to enhance students' learning of mathematical concepts (Indrapangastuti et al., 2021; Setyaningrum, 2018). BL is distinct from other student-centered approaches in its specific integration of technology and conventional classroom methods.

In BL, students can engage with learning resources at their own pace, revisiting materials and practicing exercises as needed (Lin et al., 2017). Online assessments, coupled with immediate feedback, contribute to enhancing the effectiveness of teaching (Lin et al., 2017). Integration of learning platforms like Google Classroom further increases students' capacity to establish social connections in search of knowledge (Ni, 2020). Thus, BL also promotes collaborative learning (Lin et al., 2017).

Moreover, BL approach is flexible vis-à-vis time, location, and accessibility (Tang & Chaw, 2013). BL increases students' motivation by offering a flexible and accommodating way to manage time, addressing individual learning preferences, and fostering autonomy, which ultimately cultivates independence and a sense of responsibility in their educational experience (Tuomainen, 2016). Furthermore, it has been argued that when applied independently, blended learning performs better than both strategies (Mozelius & Hettiarachchi, 2017). However, BL approach is mainly implemented in higher education to a very minimum and not yet practiced in Ethiopian secondary schools (MoE, 2015).

The primary purpose of this study is to assess the effect of the BL model on students' conceptual understanding of mathematics compared to conventional teaching methods. The study will compare BL, which integrates online and face-to-face instruction, with conventional in-person methods to determine which approach more effectively enhances students' grasp of mathematical concepts. The results will provide insights into the effectiveness of digital resources in education and could influence educational practices and policies, potentially leading to broader adoption of BL or reaffirming traditional methods.

Research Aim

The specific objective of the study is to assess the impact of blended learning, using the lab rotation model in secondary schools, on students' conceptual understanding of mathematics. In this era of rapid technological advancement, it is anticipated that BL will become one of the interactive learning tools that mathematics teachers can use to introduce students to new methods of teaching mathematics by overcoming the benefits and drawbacks of its use in the classroom and computer lab.

As a result, the following research hypotheses were formulated:

- H₀₁ There is no statistically significant mean score difference in students' mathematics conceptual understanding of grade ten taught using the blended learning educational model and the conventional educational method.
- H₀₂ There is no significant mean difference between the pre-test and post-test mean score of conceptual understanding of mathematics within a group.

Research Methodology

Research Design

This quantitative study utilized quasi-experimental with non-equivalent pre-test and post-test design. In this case, hypotheses were speculated about relationships between variables, while variables represent concepts with differing values. Quasi-experimental research design is frequently utilized in quantitative research (Håkansson, 2013). In this design, two groups of grade-10 students were selected from two intact classes of secondary schools in Ethiopia, which are geographically located in the same region, both have computer centers, and have equivalent settings.

The primary objective is to assess the effect of utilizing a lab rotation-based BL model, facilitated through the Learning Management System (LMS)-Google Classroom, on mathematics conceptual understanding. The study spans 20 weeks, totaling 27 hours, which averages to approximately 1.35 hours per week. This schedule allows for a consistent and manageable study routine over the course of the study period. Both the experimental group (EG) and the comparison group (CG) use the same course materials. The EG received an intervention that combined online learning with traditional teaching methods, while the CG received standard face-to-face instruction without any BL component. Both EG and CG received the same pre-test, which was Mathematics Conceptual Understanding Test (MCUT). Following the interventions, a post-test with identical question types was given to each of the two groups for assessment. The pre-and post-tests cover the same material and learning objectives. The questions are all identical and have consistent formats and types. To guarantee a trustworthy comparison, both questions have the same degrees of difficulty and cover the same topics.

Table 1
An Overview of the Research Process

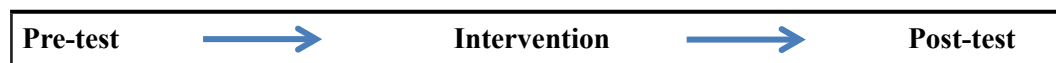


Table 1 illustrates that the pre-test involves assessing students' prior knowledge and understanding of the subject matter before introducing any intervention, serving as a baseline to gauge initial conceptual understanding and identify areas needing improvement. During the intervention phase, either the BL educational model or conventional approaches are implemented, incorporating various instructional strategies and activities aimed at enhancing students' mathematical conceptual understanding. Following the intervention, a post-test is administered to evaluate changes in students' understanding compared to their pre-test scores, thereby assessing the effectiveness of the educational approach used.

Sample

The study included 83 grade 10 students from Nekemte city in the Oromia regional state of Ethiopia during the 2023/2024 academic year. The participants, aged 15 to 20, were selected to provide insights into the educational experiences and outcomes of high school students in this region.

This study used a three-stage sampling technique. In the first stage, two secondary schools in the city were selected using purposive sampling. The criteria for ensuring equivalency in the selection process including the presence of computer labs, access to internet connection, teachers with comparable qualifications and experience, and similar demographic profiles. Purposive sampling is employed by researchers when they anticipate that specific conditions will yield valuable data (Fraenkel & Wallen, 2009). In the second stage, two intact classes

were randomly selected from both schools. Students' performance results in mathematics from the previous semester of the two selected intact classes were thoroughly analyzed. The result indicates that both groups were equivalent. This selection process ensured that the schools had a similar academic standing, allowing for a more controlled comparison of outcomes in the subsequent research or intervention. By choosing these intact classes, the study aimed to maintain the natural classroom environment while minimizing differences that could affect the validity of the results.

In the final stage of the sampling procedure, the simple random sampling method was employed to ensure an unbiased selection process. This method involved randomly assigning the two schools to different groups, thereby minimizing any selection bias. As a result of this process, one school was designated as the CG, where students would continue with the conventional teaching methods. The other school was assigned as the EG, where students would implement the BL strategy. This random assignment was crucial in maintaining the integrity of the study, ensuring that any differences observed between the two groups could be attributed to the teaching methods rather than pre-existing differences between the schools. As a result, 38 students in the EG were assigned to utilize a BL strategy, whereas 45 students in the CG continued with conventional teaching practices.

Instruments

The main instrument used in this study is a consisting of 18 multiple-choice questions developed by the researcher and mathematics teacher in the secondary school. The conceptual understanding of mathematics was assessed using a two-tiered test that included both a pre-test and a post-test. The MCUT evaluates students' understanding of mathematical concepts. This diagnostic test consists of two parts: the first tier involves answering content-related questions, while the second tier includes multiple-choice questions and a blank space for further explanation.

The Pre-Test measures students' baseline knowledge and understanding of mathematical concepts before any intervention or instructional activity. It assesses their initial understanding of the topics selected, establishing a starting point for each student's knowledge and concepts. In contrast, the Post-Test assesses students' understanding of the same concepts after the intervention or instructional activity, aiming to determine any changes or improvements in their knowledge. Data collection occurred over a 20-week period, from September 2023 to February 2024.

A table of specifications defining the content areas was also made. To guarantee that propositional knowledge was allocated equitably among the mathematics topics, this table was used. Thus, from relation and function 5 items, from polynomial function 6 items, exponential and logarithmic functions 7 items were developed and piloted.

After the pilot study, the tool's validity and reliability were assessed using the KR-20 coefficient, which was 0.72, greater than 0.5 indicating acceptable reliability (Andale, 2017). The discrimination index (.39) and mean difficulty level (.36) were also within acceptable limits (Boopathiraj & Challamani, 2013). KR-20 was chosen due to the varying difficulties of the test items, reflecting diverse student abilities and subject complexity.

Different methods are employed in the literature to assess the two-tier test item. Scoring in the Two-Tier Multiple-Choice Test (TTMCT) isn't significantly distinct from scoring in a regular multiple-choice test, where correctness in both the initial and subsequent tiers is emphasized (Adesoji & Omilani, 2012). The scoring method utilized in this study follows the approach outlined by (Yamtinah, 2015) and is thoroughly explained in Table 2. It was successful in utilizing this test to assess students' understanding and identify contrasting ideas. The two-tier test used to measure students' conceptual understanding of mathematics is evaluated according to the criteria shown in Table 2.

Table 2
Criteria for Evaluation of Two-Tier Multiple Choice Test

No	Aspects of Assessment	Score
1	Wrong answer-Wrong reasons or did not answer	0
2	Wrong answer-right reason	1
3	Right answer- wrong reason	2
4	Right answer- right reason	3

The criteria detailed in Table 2 were utilized to systematically evaluate each item on the test. Each item was rated according to these predefined standards, which ensured a consistent and objective assessment of the students' responses. Based on these evaluations, the total scores for each student was calculated, reflecting their performance across all test items. The test is designed with a scoring range that spans from a minimum of 0 to a maximum of 100. This range allows for a comprehensive measure of student achievement, with higher scores indicating better performance and understanding of the material covered.

Intervention Procedures

In a pre-experiment interview, it was revealed that while instructors were adept with computers, they were unaccustomed to online learning and integrating courses with technology. To address this, teachers with Master's degrees in mathematics education and ICT teacher for assisting the treatment group, possessing equivalent secondary school teaching experience, were recruited for both the intervention and comparison groups. These teachers took ten days of training, which covered online teaching, integrating mathematics with technology and the use of the Google Classroom platform through lab rotation and conventional learning methods. Specialized training was given for mathematics teachers emphasizing face-to-face teaching strategies and focusing on their assessment and instructional techniques. Orientation was also given to the students in the treatment group, as well as to the comparison group concerning the purpose of the study.

Pre-test was subsequently administered to both groups simultaneously in order to establish baseline levels of the dependent variable, such as students' conceptual understanding of mathematics, before introducing any intervention. These pre-tests serve as a crucial starting point, allowing researchers to measure each student's initial proficiency and identify any existing gaps in knowledge and concepts. The data collected from these pre-tests provide a reference point against which the effectiveness of the intervention can be measured, enabling a clearer comparison of any changes that occur during the study. The EG undergoes a structured intervention program over a period of 20 weeks. During this time, students in the EG are exposed to the BL educational model or other targeted instructional strategies designed to enhance their mathematical understanding. These interventions include a mix of online and in-person activities.

In the EG, students are guided on how to use online learning resources and are introduced to BL concepts. The Google Classroom Learning Management System is used to create an invitation link for the online learning platform, making it accessible to students at <https://classroom.google.com/c/NjMwMjU4MzczNjc?cjc=laktent>. To become part of the researcher-led group classroom and gain system access, students must first establish an email account and then enter the passcode invitation supplied by the researcher and/or paraprofessional. Students had to use their unique accounts to log in in order to support continuous learning. The online learning platform, which includes a number of features like lesson distribution, feedback gathering, assignments, and discussion forums, was created particularly to support conventional in-person instruction. Through the online interface, students can then actively interact with all of the instructional content that their teacher or researcher has provided.

In contrast, the CG continues with their regular classroom instruction without any additional intervention or modification to their existing learning methods. This setup allows for a clear comparison of outcomes between the group receiving the intervention and the group that does not, helping to determine the effectiveness of the educational model being tested.

In the CG, the instructional method employed was the conventional lecture approach. The mathematics teacher adhered to the typical practice of delivering content through conventional lectures, a method commonly employed in secondary schools across Ethiopia. In this approach, the instructor presented the subject matter and demonstrated sample examples, while the participants took notes, listened actively to the lectures, and transcribed formulas. Notably, this instructional strategy did not incorporate the use of technology-based resources.

In this study, although the two groups were taught by different teachers, both educators adhered to identical instructional methods and strategies during their face-to-face sessions. This approach was deliberately chosen to maintain consistency and ensure that any differences in student outcomes could be attributed to the intervention rather than variations in teaching styles. Both teachers employed a uniform set of instructional techniques, including group work, collaborative problem-solving activities, and guided discussions, which were integral to fostering a similar learning environment for both groups. Additionally, the same assessment methods were applied, ensuring that students in both groups were evaluated using identical criteria and standards. This consistency in instructional delivery and assessment was crucial for maintaining the integrity of the study's comparison between the EG and CG.

After the intervention was completed, the MCUT was administered as a post-test to evaluate the conceptual understanding of the different groups involved in the study. This test aimed to measure how well students understand various mathematical concepts after the interventions had been implemented. Secondary school students in both the EG and CG independently completed the MCUT at two points: once before the interventions began (pre-test) and once after the interventions concluded (post-test).

Importantly, both groups were exposed to the same mathematical content during the study, ensuring that any differences in post-test results could be attributed to the intervention methods rather than variations in the material covered. At the end of the classroom activities, the researchers provided detailed feedback on the intervention process. This feedback was intended to refine and improve the strategies used in future implementations, ensuring that the most effective methods for enhancing students' conceptual understanding in mathematics are identified and applied.

Data Analysis

Levene's test and tests for normality are commonly used in statistical analysis to assess the assumptions required for various parametric tests, such as ANOVA or t-tests. The obtained data were analyzed by comparing the pre-test and post-test of both assessments. Descriptive statistics for each test were used to summarize and organize the data, providing a clear overview of its main features. This study also uses inferential statistical methods to draw conclusions or make predictions about a larger population based on a sample of data.

A one-way ANOVA is used to compare the means of the independent groups to determine if there are statistically significant differences among them, making it ideal for experiments. The rationale for choosing one-way ANOVA (Analysis of Variance) and paired sample t-test in data analysis hinges on their specific applications for comparing means. In contrast, the paired sample t-test is employed when comparing means from the same group at different times or under two different conditions, assessing whether the mean difference is statistically significant or not. These tests enable researchers to analyze data by considering both two group comparisons and within-group variations, offering a comprehensive understanding of the results. The data were analyzed using SPSS version 22.0.

Ethical Consideration

Ethical considerations were carefully addressed throughout the study, with full consent from the involved school. The study was conducted with academic objectives, as clarified in official correspondence from the school. Throughout every stage, the researchers prioritized ethical principles such as integrity, impartiality, fairness, and maintaining respectful relationships with the school involved. They aimed to provide an unbiased account of the findings, ensuring relevance to all stakeholders, especially the secondary school offering the subject. Before publishing the study as a permanent research document, the researchers submitted the final report and findings to Jimma University in digital formats, seeking formal acknowledgment through an online presentation.

Research Results

To proceed with analyzing the results, it's crucial to check the data for normality and homogeneity. Evaluating these aspects ensures that the data meets the assumptions required for valid statistical analysis and provides a foundation for reliable interpretation of the results.

To assess normality, skewness and kurtosis values were utilized, while Levene's test was employed to evaluate homogeneity. Table 3 displays the pre-and post-test homogeneity of variance for the MCUT between the groups.

Table 3
Skewness, Kurtosis, and Levene's Tests Analysis of MCUT

DV	Group	N	Skewness	Kurtosis	Levene's test	
					F	p
Pre-MCUT	EG	38	-.065	-.155	.069	.793
	CG	45	-.021	-.303		
Post-MCUT	EG	38	.152	-1.406	3.095	.069
	CG	45	.203	-.847		

Table 3 outlines the characteristics of the dependent variables, Pre-MCUT and Post-MCUT, measured before and after the intervention. It distinguishes between the EG and the CG, with sample sizes of 38 and 45, respectively. Skewness values for both groups are close to zero, indicating relatively symmetric distributions, with slight right skewness observed in the post-test scores. Kurtosis values reveal that both pre-test and post-test distributions are flatter compared to a normal distribution.

Levene's test assesses the equality of variances between the groups. For the pre-test, the F-value of .069 and p-value of .793 suggest no significant difference in variances between EG and CG. For the post-test, the F-value of 3.095 and p-value of .069 indicate marginal evidence of a variance difference. These results are essential for determining the suitability of statistical tests for further analysis, ensuring that assumptions of equal variances are adequately addressed.

Table 4

Descriptive Analysis of MCUT Scores from Pre-Test and Post-Test, between Groups

DV	Group	N	M	SD	SE
Pre- CU	EG	38	27.88	7.89	1.28
	CG	45	26.14	7.57	1.13
Post- CU	EG	38	42.20	7.12	1.54
	CG	45	34.36	5.96	0.8

Note. Pre-Cu means Pretest of Conceptual Understanding, Post-CU means Posttest of Conceptual Understanding

The difference between these variances in Table 4 shows that the group with a variance of 14.17 has more variability in scores, meaning there is a greater range of performance levels, while the group with a variance of 7.12 exhibits more uniformity in scores. A higher variance of 14.17 indicates a broader range of performance levels within the group, suggesting that students' scores are more dispersed around the mean. This implies that the intervention or instructional method had varying effects on different students; with some benefiting significantly while others do not, leading to a wider range of outcomes.

Table 4 also shows that the mean post-test score for the EG was significantly higher compared to that of the CG, indicating a notable overall improvement.

Table 5

A One-Way ANOVA Analysis of Pre-test Scores for MCUT

	Variables	SS	df	MS	F	p	Eta Squared
Pre-Cu	Between Groups	62.626	1	62.626	1.053	.308	.013
	Within Groups	4816.395	81	59.462			
	Total	4879.021	82				

Note. Pre-CU means Pre-test of Conceptual Understanding

From Table 5, the ANOVA results ($F(1, 81) = 1.053, p > .05$) show that there was no significant difference in pre-test scores among the groups. This suggests that the groups were almost equivalent before the intervention.

H_{01} : There is no statistically significant mean score difference in students' mathematics conceptual understanding of grade ten taught using the blended learning educational model and the conventional educational method.

To assess if there were significant differences in the post-test mean scores between the EG and CG ANOVA test was conducted. The results of this analysis are presented in Table 6.

Table 6

A One-Way ANOVA Analysis of post-test Scores for MCUT

	Variables	SS	df	MS	F	p	Eta Squared
Cu-post	Between Groups	1266.198	1	1266.198	29.867	.002	.269
	Within Groups	3433.932	81	42.394			
	Total	4700.134	82				

Note: Pre-CU means Pre-test of Conceptual Understanding, SS- Sum Square, MS- Mean Square

According to Table 6, there was a statistically significant difference in the conceptual understanding of mathematics between the groups ($F(1, 81) = 29.867, p < .05$). As a result, the null hypothesis (H_{01}) was rejected. The eta square value ($\eta^2 = .269$) signifies a significant impact of the treatment on the dependent variable.

H_{02} There is no significant mean difference between the pre-test and post-test mean score of conceptual understanding of mathematics within a group.

Table 7
Paired Sample T-Test of Pre-Test and Post-Test Results on MCUT

Group	Variables	Paired differences			<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
		<i>MD</i>	<i>SD</i>	<i>SE</i>				
EG	Post CU – pre CU	14.327	11.397	1.848	7.740	37	.0001	1.016
CG	Post CU – pre CU	8.231	9.051	1.351	6.101	44	.0004	.408

Note. *MD* means Mean Difference

Table 7 shows that, for the EG, the average difference between the post-test and pre-test scores was 14.327, with a *t*-value of 7.740 and a $p < .001$, showing a significant enhancement in post-test performance. The effect size for EG, Cohen's $d = 1.016$, indicates a large effect. Similarly, the comparison group's post-test and pre-test scores were 8.231, with a *t*-value of 6.101 and a $p < .001$, indicating a significant improvement from pre-test to post-test. The effect size, Cohen's $d = 0.408$, suggests a medium effect (Cohen, 1988).

Since the *p*-value for post-test is less than 0.05, we reject the null hypothesis or research hypothesis 2. This result indicates that students who participated in technology-integrated BL outperformed those who received conventional instruction. The *p*-value, being below 0.05, provides strong evidence against the null hypothesis, confirming that technology-integrated learning significantly enhances student performance relative to conventional methods. These findings support the implementation of technology in educational settings to improve learning outcomes.

Discussions

In the 21st century, advancements in science and technology significantly influence education, necessitating the integration of technology into teaching methods (Alsalmi, 2020). Technology aids teachers in creating more accessible and engaging learning materials. In the Era 4.0, technology enables learning without physical presence, using tools like Google Classroom. BL, which combines online and face-to-face instruction, is one such method that enhances students' skills and knowledge while incorporating innovative technologies (Jani et al., 2018; Rahmat, 2020). Research indicates that blended learning significantly improves students' conceptual understanding and critical thinking skills, offering flexible schedules and easy access to materials, which students find beneficial (Suana et al., 2020). This approach also helps reduce misconceptions by allowing for a better understanding of theoretical concepts and open communication with teachers (Kesuma et al., 2020).

Data is considered normally distributed when kurtosis and skewness values range between -2 and 2, a condition that is met in this study (Field, 2009). Levene's test results also indicate equality of variances for the mathematics conceptual understanding scores in both the experimental and comparison groups, with $p < .05$, confirming that assumptions of equal variances are met. The findings align with the research hypothesis and adhere to the necessary criteria for one-way ANOVA, including normal distribution, equal variances, random sampling, independence of scores, and adequate data collection (Field, 2009).

The ANOVA results for Pre-Cu, which measures conceptual understanding before the intervention, show no significant difference between groups ($p = .308$) and a small effect size ($\eta^2 = .013$), indicating prior to the intervention, the groups were comparable in terms of their conceptual understanding. However, the post-test results reveal a significant difference between groups with an $F = 29.867$ and $p = .002$, reflecting a large effect size ($\eta^2 = .269$) (Cohen's, 1988). This substantial effect suggests that the BL intervention significantly improved grade 10 students' performance in mathematics conceptual understanding. Given these findings, the BL approach appears effective and merits further consideration and expansion. Future research with larger samples and additional variables could provide more detailed insights into the specific aspects of BL contributing to its effectiveness.

The results obtained from the paired sample t-test indicate significant improvements in post-test scores for both the EG and the CG compared to their pre-test scores. Specifically, the EG showed a substantial mean difference (MD) of 14.327 with a large Cohen's $d = 1.016$, suggesting a strong effect of the intervention. In contrast, the CG showed a smaller mean difference of 8.231 with a medium Cohen's $d = .408$, indicating a moderate effect size and a more modest improvement in scores. These findings suggest that while both groups experienced gains, the intervention applied to the EG was more effective in significantly improving their outcomes compared to the control group.

The findings of this study were in line with previous research, including studies by (Fitri & Zahari, 2019; Lin et al., 2017; Setyaningrum, 2018; Ulfa & Puspaningtyas, 2020), which demonstrated the positive impact of BL on students' mathematical understanding. These earlier studies demonstrated that the BL model effectively enhances students' understanding of mathematical concepts by integrating online and conventional learning methods. The combination of flexible online resources and face-to-face instruction was shown to deepen students' conceptual comprehension. This consistency across multiple studies reinforces the value of BL as an effective approach in mathematics education.

Similarly, the study is also consistent with the findings of (Clarisa & Putra, 2022; Sundari et al., 2023; Walid, 2023), which state that utilizing Google Classroom for BL can enhance conceptual understanding in mathematics. Google Classroom serves to address specific constraints faced by teachers and students, particularly concerning time, space, conditions, and circumstances (Indrapangastuti et al., 2021). Additionally, BL stands out as a viable alternative for enhancing students' conceptual understanding of mathematics (Helsa et al., 2023; Indrapangastuti et al., 2021; Setyaningrum, 2018).

Overall, the originality of this study lies in its demonstration of how combining BL with lab rotation, specifically through Google Classroom, significantly benefits students' conceptual understanding of mathematics. This approach influences the strengths of both online and offline learning environments, as discussed by (Helsa et al., 2023; Indrapangastuti et al., 2021), to provide a more comprehensive educational experience. The positive outcomes observed align with previous studies that emphasize the effectiveness of BL in improving students' problem-solving skills and critical thinking abilities in mathematics (Huda et al., 2019; Ulfa & Puspaningtyas, 2020), showcasing its potential as a powerful tool for enhancing educational practices.

Conclusions and Implications

The study found that BL improved students' mathematical understanding. These results also suggest that BL is an effective educational approach for enhancing conceptual understanding in mathematics. Depending on these findings of the study, it can be concluded that the BL model enhances mathematical learning in several significant ways. Firstly, it fosters a deeper understanding of mathematical concepts by employing diverse instructional approaches such as simulations, visualizations, and interactive problem-solving exercises. This multifaceted approach engages students more thoroughly, allowing them to explore concepts from various

angles. Secondly, the integration of technology in BL cultivates critical thinking skills among students. By tackling complex problem-solving tasks and delving into mathematical concepts in greater depth, students are encouraged to think critically and analytically. Thirdly, BL environments support learning through adaptive technologies. These technologies adapt the task difficulty according to each student's performance, offering personalized support to improve conceptual understanding. These findings are substantiated by a study demonstrating that students in BL settings exhibit improved comprehension of mathematical concepts compared to those in conventional learning environments.

In conclusion, this study demonstrates that BL via Google Classroom significantly enhances students' conceptual understanding of mathematics compared to conventional teaching methods. The study highlights the effectiveness of the BL approach, particularly with lab rotation, in improving learning outcomes for secondary school students. Hence the following recommendation can be highlighted:

1. Secondary school mathematics teachers should understand that the BL model enhances students' understanding of math concepts by offering an engaging and varied learning experience. Using diverse methods such as simulations, visualizations, and interactive exercises helps cater to different learning styles and improves comprehension.
2. Curriculum designers and stakeholders should acknowledge the effectiveness of BL in improving mathematical understanding and integrate its elements into the curriculum. Emphasis should be placed on creating instructional materials that support both digital and in-person learning to enhance student engagement and comprehension.
3. Further research is needed:
 - i. To investigate the impact of the BL model in other subjects and to assess how factors like sex, socioeconomic background, and learning preferences affect its effectiveness.
 - ii. To address these gaps and optimize the use of modern educational technologies to fully realize the potential of BL in different educational contexts.

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Declaration of Interest

The authors declare no competing interest.

References

- Adesoji, F., & Omilani, N. (2012). A comparison of secondary school students' levels of conception of qualitative and quantitative inorganic analysis. *American Journal of Scientific and Industrial Research*, 3(2), 56–61. <https://doi.org/10.5251/ajsir.2012.3.2.56.61>
- Albhnsawy, A. A., & Aliweh, A. M. (2016). Enhancing student teachers' teaching skills through a blended learning approach. *International Journal of Higher Education*, 5(3), 131–136. <https://doi.org/10.5430/ijhe.v5n3p131>
- Alebaikan, R., & Troudi, S. (2010). Blended learning in Saudi universities: Challenges and perspectives. *ALT-J*, 18(1), 49–59. <https://doi.org/10.1080/09687761003657614>

- Albiladi, W. S., & Alshareef, K. K. (2019). Blended learning in English teaching and learning: A review of the current literature. *Journal of Language Teaching and Research*, 10(2), 232–238. <https://doi.org/10.17507/jltr.1002.03>
- Almazroa, H., & Alotaibi, W. (2023). Teaching 21st century skills: Understanding the depth and width of the challenges to shape proactive teacher education programmes. *Sustainability*, 15(9), Article 7365. <https://doi.org/10.3390/su15097365>
- Alsalthi, N. R. (2020). *The effects of the use of the know-want-learn strategy (KWL) on fourth grade students' achievement in science at primary stage and their attitudes towards it*. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(4). <https://doi.org/10.29333/ejmste/115165>
- Baiduri. (2019). "Literacy strategies in mathematics education in the industrial era." 4.0. *MUST: Journal of Mathematics Education, Science and Technology*, 4(1), 77–94. <http://dx.doi.org/10.30651/must.v4i1.2782>
- Benson, V., Anderson, D., & Ooms, A. (2011). Educators' perceptions, attitudes, and practices: Blended learning in business and management education. *Research in Learning Technology*, 19(2), 143–154. <https://doi.org/10.1080/21567069.2011.586676>
- Berga, K. A., Vadnais, E., Nelson, J., Johnston, S., Buro, K., Hu, R., & Olaiya, B. (2021). Blended learning versus face-to-face learning in an undergraduate nursing health assessment course: A quasi-experimental study. *Nurse Education Today*, Article 104622. <https://doi.org/10.1016/j.nedt.2020.104622>
- Boopathiraj, C., & Chellamani, K. (2013). Analysis of test items on difficulty level of and discrimination index in the test for research in education. *International Journal of Social Science & Interdisciplinary Research*, 2(2), 189–93.
- Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry education research and practice*, 8(3), 293–307. <https://doi.org/10.1039/B7RP90006F>
- Clarisa, C. A. O., & Putra, F. G. (2022). The effect of Google classroom's assisted blended learning model on mathematical concepts understanding and mathematical dispositions. *Journal of Educational Technology*, 2(1), 30–39. <https://journal.iaimnumetrolampung.ac.id/index.php/jtep/article/view/2627>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum.
- Field, A. (2009). *Discovering statistics using SPSS: Book plus code for E version of text*. Sage.
- Fitri, S., & Zahari, C. L. (2019). The implementation of blended learning to improve understanding of mathematics. *Journal of Physics: Conference Series*, 1188(1), Article 012109. <https://doi.org/10.1088/1742-6596/1188/1/012109>
- Håkansson, A. (2013). Portal of research methods and methodologies for research projects and degree projects. In *The 2013 World Congress in Computer Science, Computer Engineering, and Applied Computing WORLDCOMP 2013; Las Vegas, Nevada, USA, 22–25, 67–73*. CSREA Press USA. <https://www.diva-portal.org/smash/get/diva2:677684/FULLTEXT02>
- Helsa, Y., Turmudi, & Juandi, D. (2023). Hybrid learning for conceptual understanding skills in mathematics: A meta-analysis. *International Journal of Information and Education Technology*, 13(2), 355–363. <https://doi.org/10.18178/ijiet.2023.13.2.1814>
- Huda, S., Firmansyah, M., Rinaldi, A., Suherman, Sugiharta, I., Astuti, D. W., & Prasetyo, A. E. (2019). Understanding of mathematical concepts in the linear equation with two variables: Impact of e-learning and blended learning using Google Classroom. *Al-Jabar: Journal of Mathematics Education*, 10(2), 261–270. <https://doi.org/10.24042/ajpm.v10i2.5303>
- Hutagalung, R. (2017). Improving students' mathematical conceptual understanding through Toba culture-based guided discovery learning at SMP Negeri 1 Tukka. *Journal of Mathematics Education and Science*, 2(2), 70–77. <https://doi.org/10.30743/mes.v2i2.133>
- Indrapangastuti, D., Surjono, H. D., Sugiman, & Yanto, B. E. (2021). Effectiveness of the blended learning model to improve students' achievement of mathematical concepts. *Journal of Education and e-Learning Research*, 8(4), 423–430. <https://doi.org/10.20448/journal.509.2021.84.423.430>

- Kemdikbud Ristek. (2019). *Education in Indonesia: Learning from the results of PISA 2018*. Jakarta: Education Assessment Center of the Research and Development Agency. <https://sim pandata.kemdikbud.go.id/index.php/s/tLBwAm6zAGGbofK>
- Kemdikbud Ristek. (2022). *Decision of the head of BSKAP number 008/H/KR/2022 regarding learning outcomes for early childhood education, primary education, and secondary education in the Merdeka curriculum*. Jakarta: Education Standards, Curriculum, and Assessment Agency of the Ministry of Education, Culture, Research, and Technology. https://kurikulum.kemdikbud.go.id/wp-content/unduh an/CP_2022
- Kesuma, G. C., Diani, R., Hasanah, N., & Fujiani, D. (2020). Blended learning model: Can it reduce students' misconception in physics? *Journal of Physics: Conference Series*, 1467(1), Article 012044. <https://doi.org/10.1088/1742-6596/1467/1/012044>
- Lin, Y. W., Tseng, L. C., & Chiang, J. P. (2017). The effect of blended learning in mathematics course. *EURASIA Journal of Mathematics Science and Technology Education*, 13(3), 741–770. <https://doi.org/10.12973/eurasia.2017.00641a>
- Ma'arop, A. H., & Embi, M. A. (2016). Implementation of blended learning in higher learning institutions: A review of the literature. *International Education Studies*, 9(3), 41–52. <https://doi.org/10.5539/ies.v9n3p41>
- Mills, S. (2016). Conceptual understanding: A concept analysis. *The Qualitative Report*, 21(3), 546–557. <https://doi.org/10.46743/2160-3715/2016.2308>
- Ministry of Education [MOE]. (2015). *Education Sector Development Program V (ESDP V)*. Author.
- MoE. (2017). *National educational assessment and exam-inactions agency Ethiopian third national learning assessment of grade 10 and 12 students*. Minister of Education.
- Ministry of Education [MOE]. (2020). *Why Ethiopia values STEM education?* <http://www.Moe.Gov.et/Web/Guest/-/Why-Ethiopia-Values-Stem-Education->
- Mozelius, P., & Hettiarachchi, E. (2017). Critical factors for implementing blended learning in higher education. *International Journal of Information and Communication Technologies in Education*, 6(2), 37–51. <https://doi.org/10.1515/ijicte-2017-0010>
- Ni, L. B. (2020). Blended learning through Google Classroom. *International Journal of Educational and Pedagogical Sciences*, 14(4), 220–226. <https://www.academia.edu/download/62934592/>
- Rahmat, I. (2020). Implementation of andragogy e-learning platform in blended learning at State University of Padang. *Journal of Education Technology*, 4(2), Article 133. <https://doi.org/10.23887/jet.v4i2.24817>
- Shand, K., & Farrelly, S. G. (2018). The art of blending: Benefits and challenges of a blended course for preservice teachers. *Journal of Educators Online*, 15(1). <https://doi.org/10.9743/jeo2018.15.1.10>
- Suana, W., Ningsih, W. S. A., Maharta, N., & Putri, N. M. A. A. (2020). The effect of blended learning setting on students' critical thinking skills in physics. *Journal of Physics: Conference Series*, 1572(1). <https://doi.org/10.1088/1742-6596/1572/1/012073>
- Suandito, B. (2017). "Informal evidence in mathematics education." Al-Jabar: "Mathematics Education Journal," 6(1), 13–24. <https://doi.org/10.24042/ajpm.v8i1.1160>
- Setyaningrum, W. (2018). Blended learning: Does it help students in understanding mathematical concepts? *Journal of Mathematics Education Research*, 5(2), 244–253. <https://doi.org/10.21831/jrpm.v5i2.21428>
- Sundari, R. V., Bilda, W., & Pradja, B. P. (2023). The effect of blended learning on the Google Classroom app on students' understanding of mathematical concepts. *Proceedings of Seminar*. <https://jurnal.umt.ac.id/index.php/pscome/article/view/9517>
- Tang, C. M., & Chaw, L. Y. (2013). Readiness for blended learning: Understanding attitude of university students. *International Journal of Cyber Society and Education*, 6(2), 79–100. <https://www.learn techlib.org/p/209223/>
- Treagust, D. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science Education*, 16(1), 199–207. <https://doi.org/10.1007/BF02356835>
- Tuomainen, S. (2016). A blended learning approach to academic writing and presentation skills. *International Journal on Language, Literature*, 3(2), 33–55. <https://doi.org/10.1515/llce-2016-0009>

- Ulfa, M., & Puspaningtyas, N. D. (2020). The effectiveness of blended learning using a learning system in network (SPADA) in understanding of mathematical concepts. *Mathematics and Learning*, 8(1), 47–60. <http://dx.doi.org/10.33477/mp.v8i1.1280>
- Walid, A. (2023). Improving conceptual understanding of mathematics through blended learning using Google Classroom. *International Journal of Education and Teaching Zone*, 2(1), 130–138. <https://doi.org/10.57092/ijetz.v2i1.122>
- Yamtinah, S. (2015). Development of diagnostic instruments for learning difficulties in chemistry in higher education. *Journal of Educational Research and Evaluation*, 19(1), 69–91.
- Zulkarnain, I., & Budiman, H. (2019). The impact of conceptual understanding on mathematics problem-solving ability. *Research and Development Journal of Education*, 6(1), 18–27. <http://dx.doi.org/10.30998/rdje.v6i1.4093>

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