THE EFFECT OF BLENDED LEARNING EDUCATIONAL MODEL ON SECONDARY SCHOOL STUDENTS' MATHEMATICS ACHIEVEMENT

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Abstract

Blended Learning has gained significant attention for its potential to enhance student achievement. However, its implementation in secondary education, especially in developing countries like Ethiopia, faces barriers such as infrastructure limitations, pedagogical challenges, and socio-economic factors. This study aimed to evaluate the effect of a blended learning model on the mathematics achievement of tenth-grade students in Ethiopia. A quasi-experimental design with non-equivalent groups, using both pre- and post-tests was employed. Two pre-existing classes from different schools were assigned to either the experimental group (n = 38) or the comparison group (n = 45) using lottery method. Prior academic records showed similar levels of mathematics achievement between the groups. A pre-test, covering topics like relations and functions, polynomial functions, and exponential and logarithmic functions, confirmed group equivalence. The data were analyzed using one-way ANOVA, which revealed that students in the blended learning group outperformed those in the conventional teaching group. A significant mean difference of 19.999 was observed, with a substantial effect size, as indicated by paired sample t-tests. These results suggest that blended learning is more effective than conventional methods in improving mathematics achievement. The study advocates for incorporating blended learning into the mathematics curriculum and urges policymakers and educators to consider adopting this model to enhance educational outcomes.

Keywords: *blended learning, mathematics achievement, quasi-experimental, secondary school*

Introduction

Conventionally, educational institutions have relied on teacher-centered classrooms, where direct instruction served as the primary method for delivering content. After lectures, students typically engaged in seatwork, using textbooks to focus on memorization and individual practice. These classrooms were usually quiet and well-organized, with little student interaction and technology use limited mainly to computer lab sessions. There was little opportunity for personalized learning or collaborative activities.

As technology and teaching practices have advanced, education has adapted to meet the evolving needs of 21st-century learners. This shift has moved classrooms from a teacher-centered approach to a more student-focused model, prioritizing individual needs over one-size-fits-all solutions. Collaborative and personalized learning emerged as key components in these student-centered environments. Moreover, the rapid growth of technology has equipped students with exceptional knowledge and skills, prompting schools to incorporate digital tools into their curriculum. As a result, Blended Learning (BL) has gained prominence, providing students with innovative and diverse learning experiences (Hermino & Arifin, 2020; Lazar et al., 2020; Syahrawati et al., 2022).

Improving students' learning outcomes requires integrating technology into education. Teachers can use various teaching strategies to leverage technology's potential in enhancing students' understanding and experiences (Hermino & Arifin, 2020). By incorporating diverse methods and tools supported by technology, students can better adapt to the demands of the digital age. The use of BL increases motivation, deepens understanding, and promotes critical thinking by encouraging activities that foster essential skills for the 21st century (Syahrawati et al., 2022). One study examined the impact of BL on secondary school students' mathematical performance (Indrapangastuti et al., 2021). Information and communication technology (ICT) has created new opportunities for learning by offering student-centered environments, expanding access to education, and providing greater flexibility. Choosing the right learning model is essential for improving student performance, particularly in challenging subjects like mathematics (Macharia, 2022; Tohir et al., 2020).

The rapid advancement of ICT has given rise to diverse perspectives on the learning process. The teacher has transitioned away from using conventional teaching methods, which primarily rely on direct instruction, lectures, rote memorization, and teacher-centered approaches. Teachers are encouraged to employ a variety of techniques that provide students with additional opportunities to learn by integrating diverse sources. BL is a student-centered approach that merges conventional in-person classrooms with online learning activities (Singh et al., 2021). The proportion of face-to-face and online learning in BL varies, with the online component typically comprising 33% to 50%, and in some cases, reaching up to 80% (Lazar et al., 2020)

The integration of technology in education is crucial for advancing learning systems. However, conventional methods that focus on lectures and memorization continue to dominate, limiting students' exposure to a broader range of learning experiences. In today's digital era, leveraging information technology, particularly internet-based learning, is essential. With widespread access to computers and the internet, both teachers and students can tap into a wealth of educational resources, enhancing learning opportunities. It has been noted that accessible online platforms that foster social learning can significantly increase engagement between teachers and students, as well as among students themselves (Samat et al., 2020).

The definition of BL is the integration of in-person classroom instruction with virtual learning opportunities (Singh et al., 2021). Despite its simplicity, this definition captures the intricate integration that offers extensive possibilities and applications. Consequently, BL is highly adaptable to evolving technologies, pedagogical strategies, and student needs while also addressing the imperative of cultivating 21st-century learners. BL dismantles conventional teaching barriers and enables the customization of learning experiences for individual students (Lindner & Schwab, 2020).

It is crucial for educational institutions to prepare students for a future dominated by digital technologies. Teaching presence involves facilitating, supporting, and guiding students' cognitive development and social interactions to attain significant educational objectives (Zhang et al., 2020). Therefore, schools must adapt and progress by effectively incorporating technology and encouraging students to take responsibility for their learning, thus equipping them with the skills needed for future success. BL, recognized for its integration of educational models, exerts a beneficial influence on the learning process. Various researchers have highlighted the link between this method and improvements in learning outcomes and student motivation, as well as its effectiveness in achieving educational goals (Tong et al., 2022). Moreover, digital education holds the promise of delivering a personalized, flexible, scalable, accessible, cost-effective, and well-supported learning experience, aligning with the high-quality standards and expectations of twenty-first-century learners (Bart et al., 2019)

Despite its numerous advantages, BL encounters several challenges. Educators need to maintain and ensure the user-friendliness of digital tools, given the heavy reliance of BL on technical resources (Luo, 2021). Limited access to internet infrastructure poses another obstacle, particularly in economically disadvantaged regions, where establishing reliable network connections is crucial for enhancing educational quality. Additionally, the adoption of online resources often involves extra expenses, such as subscriptions to databases or academic libraries, which can strain the finances of poorly funded schools. Some students may face difficulties with online learning because of unequal access to resources and limited IT literacy, which underscores the need for accessible technical support (Faturoti, 2022). Consequently, to enhance students' understanding of mathematical concepts, mathematics teachers should tailor BL instructions to accommodate students' interests and achievements.

Ethiopia faces significant challenges in student achievement, particularly in mathematics, as noted by the Ministry of Education (MOE, 2017). The MOE acknowledges the gravity of the issue, with reports from ENLA indicating difficulties among grade 10 students, particularly in ICT and overall course competence. The Ethiopian National Learning Assessment (ENLA) indicates that students are not meeting the national standards in mathematics. So, in particular, mathematics must emphasize the urgent need for interventions to address low academic achievement in Ethiopia. BL is being adopted more and more frequently in higher education institutions, as highlighted by (Nikolopoulou, (2022). According to Halverson et al. (2014), 66.1% of the most frequently cited publications on BL pertained to higher education, whereas a mere 1.8% addressed K–12 education. This suggests that secondary schools have adopted BL significantly less than higher education institutions.

In Ethiopia, the national learning assessment for mathematics reveals persistent challenges in student achievement, as documented by the National Educational Assessment and Examinations Agency (NEAEA, 2014). These challenges stem largely from ineffective instructional practices and the inherent complexity of the subject. While the assessments primarily target grades 10 and 12, their findings underscore issues that originate in earlier stages of secondary education, which serve as a foundation for academic success. Similarly, university entrance examinations, as highlighted by Tesfa (2014), mirror these concerns, underscoring the critical need for targeted strategies to enhance students' conceptual grasp, academic outcomes, and motivation–key factors in advancing the nation's development.

Student underachievement in mathematics remains a critical issue in Ethiopia, as underscored by the Ministry of Education (MOE, 2017) and NEAEA (2014). Conventional teaching practices are widely regarded as a contributing factor to poor performance in mathematics and science (Beyessa, 2014). National assessments, such as those by Lamas (2015), reaffirm this concern, revealing that the average mathematics score for Grade 10 students was just 34.7%, far below the 50% benchmark set by the MOE (Woldetsadik & Bank, 2013). This persistent gap highlights the urgency of addressing instructional quality, especially amid ongoing educational reforms and economic development priorities.

Blended learning offers a promising approach to improving mathematics education in Ethiopia. By integrating face-to-face instruction with online resources, it provides flexible learning opportunities, access to diverse materials, and real-time interactions (Singhal, 2017). This approach fosters engagement, overcomes the limitations of conventional teaching, and enhances academic outcomes.

Research Aim

The specific objective of the study is to present the effect of blended learning, using the lab rotation model in secondary schools, on students' mathematics achievement. Specifically, the study has examined how the integration of online and face-to-face instruction in the BL model has affected students' achievement in mathematics. The findings aim to provide insights into the efficacy of digital resources in education, offering guidance for future educational practices and policies in both secondary and higher education settings.

As a result, the following research hypotheses are formulated:

- Ha_1**:** There is a statistically significant difference in post-test mathematics achievement scores between students taught using the BL model and those taught using conventional methods.
- Ha_2**:** There is a significance effect size between the BL model and conventional method in post mathematics achievement test.

Research Methodology

Research Design

The study employed a quasi-experimental design with pre-and post-tests for a non-equivalent control group. The researcher assigned students to two distinct groups: the EG at one secondary school and the CG at another. The EG has received interventions through a BL strategy that combined online and face-to-face elements within the lab rotation model. In contrast, the CG was not subjected to interventions and was taught using conventional methods. In the lab rotation model, students rotate through designated stations based on a predetermined schedule. This approach allows schools to organize flexible timetables with educators and support staff, optimizing the use of available computer labs (Graham, 2009).

Table1
Non-equivalent Group Design

Group	Pre-Test	Treatment	Post-Test
Experimental	O	BL	O
Comparison	O	-	O

O: Pre-test and post-test

The experimental design presented in Table 1 consists of two groups: the EG and the CG. Prior to the treatment, both groups take a pre-test to establish baseline measurements. The EG then receives the BL intervention, while the CG does not receive any treatment. Afterward, both groups complete a post-test to evaluate the effects of the intervention.

To minimize the influence of teachers and ensure that observed changes are due to the intervention, quasi-experimental designs employ several strategies. Key techniques include matching classrooms or schools with similar characteristics to reduce bias, even when random assignment is not fully feasible. Both the CG and EG receive identical educational materials to ensure consistency in content delivery. Comprehensive teacher training ensures educators in both groups are equally equipped to deliver the content. Additionally, outstanding teachers and students to the intervention's details reduce bias by preventing awareness of group assignment.

Further techniques include using structured lesson plans to standardize content delivery and conducting regular monitoring and fidelity checks to ensure the intervention and control conditions are implemented as planned. This involves classroom observations, teacher self-reports, and checklists. Controlling for teacher variables, such as experience and teaching style, helps account for their potential effect on outcomes. Lastly, administering pre-tests and post-tests allows researchers to measure changes in student outcomes and compare gains between groups, isolating the effect of the intervention. By employing these methods, the researchers accurately attribute changes to the intervention rather than to differences in teacher influence.

The BL model significantly improved students' procedural, conceptual, and problem-solving skills, boosting mathematics achievement in the experimental group. By combining conventional and digital methods, BL creates a personalized learning experience that empowers students to take ownership of their education. It enables learners to progress at their own pace, ensuring mastery of each concept before advancing to more complex material. Moreover, BL removes time and location constraints, providing students with flexible access to learning resources and study sessions at their convenience. As a result, students become more self-directed, leading to increased motivation and better academic achievement.

In this study, both the EG and CG covered the same key mathematical concepts, including relations and functions, polynomial functions, and exponential and logarithmic functions. The EG used a blended learning model, incorporating online lessons, interactive tools, and group discussions, allowing students to explore real-world applications and receive personalized support. In contrast, the CG followed conventional methods with direct instruction, textbook exercises, and focusing more on individual practice and theory-based learning. This approach provided the EG with a more dynamic, interactive learning environment, while the CG relied on conventional teaching strategies.

In general, the BL model enhances mathematics achievement by improving procedural skills through repeated access to online resources and practice exercises. It aids conceptual understanding with interactive simulations and visualizations, allowing students to reinforce abstract concepts. BL also increases problem-solving skills by exposing students to diverse activities and providing immediate feedback. It promotes self-learning and autonomy, enabling students to explore topics in-depth and at their own pace, building confidence and motivation. The flexibility and accessibility of BL allow students to learn in environments that suit their schedules and preferences, leading to more effective outcomes. These personalized learning experiences significantly contribute to the experimental group's improved mathematics achievement.

Table 2
Comparison of Facilitation Methods between Experimental and Comparison Groups

Aspect	Experimental Group	Comparison Group
Teaching Model	Blended learning (online resources + face-to-face interactions).	Conventional teaching methods (lectures, board exercises, textbook problems).
Instructional Approach	Interactive, multimedia-rich modules, online, and video	Direct instruction and individual practice
Technology Use	Digital tools like Google classroom and online simulations	None
Engagement Activities	Group discussions, problem-solving, and real-world application-based activities	Theory-based exercises and board demonstrations, group discussion, and problem solving
Support Provided	Personalized support through online and discussion boards	Teacher guidance primarily in class.
Content Delivery	Dynamic, emphasizing conceptual understanding and collaboration	Static, focused on procedural practice and rote learning
Real-World Applications	Emphasized (e.g., population growth)	Limited focus on real-world connections

Thus table 2 highlights the differences in facilitation methods, emphasizing the dynamic and interactive learning experience provided to the experimental group compared to the conventional approach used for the comparison group.

Sampling

The study was conducted with two grade ten classes from Nekemte City, Oromia, Ethiopia, during the 2023–2024 academic years. A total of 83 students, aged 15 to 20, participated, with 38 assigned to the EG and 45 to the CG. The participants were comparable in terms of their learning backgrounds and experiences, ensuring group homogeneity. The use of intact classes, a common approach in education studies, preserved the natural classroom environment and minimized disruptions to existing group dynamics, providing a more authentic representation of real-world learning settings.

The study employed a three-stage sampling approach. First, two secondary schools in the town were selected using purposive sampling based on specific criteria: The presence of computer labs, internet connectivity, teachers with similar qualifications and experience, and comparable student demographics. This method ensured the inclusion of schools with characteristics that would provide meaningful insights (Tongco, 2007). Next, intact classes were selected from the two schools using simple random sampling. This approach ensured that all classes within each school had an equal chance of being included in the study, thereby minimizing selection bias. By maintaining the integrity of existing class groupings, this method preserved the natural classroom dynamics, which was crucial for the validity of the intervention and subsequent comparisons between the EG and CG.

In the final stage, a lottery method was used to assign two intact classes to the EG and CG. Consequently, Nekemte Secondary School was assigned to the EG, comprising 38 students who used a BL strategy, while Dalo Secondary School was assigned to the CG, comprising 45 students who followed a conventional teacher-led teaching method with a structured sequence of textbook-based activities and demonstrations.

Instruments

In this study, a meticulously designed mathematics achievement test (MAT), detailed in Appendix A and comprising multiple-choice questions, was utilized as the primary research instrument. To ensure the test's quality, a preliminary trial was conducted with 30 questions, which were then evaluated for validity, difficulty, discrimination index, and reliability. After this evaluation, 24 items were selected form the final achievement test.

Both the experimental and comparison groups took identical pre-tests to assess their initial abilities before receiving different treatment protocols. Following the intervention, the two groups completed two progressive tests to measure their learning progression. Finally, after the instructional period, both groups underwent an equitable post-test to evaluate the effectiveness of the respective learning models. This process allowed for a clear comparison of the effect of the BL and conventional learning approaches on students' mathematics achievement.

Validity

Validity in research refers to the degree to which a study, its components, conclusions, and subsequent applications can be considered of high, low, or intermediate quality. This concept extends beyond singular truths and encompasses various dimensions, including internal, external, construct, and statistical validity (Becker et al., 2016). Internal validity was maintained by ensuring homogeneity among participants (same class), while external validity was minimized by sampling from the same school to ensure representativeness. Construct validity was addressed through careful selection of instruments, data analysis, and interpretation in line with classical test theory. Statistical validity was optimized by employing descriptive and inferential statistics, with assumptions tailored to the research questions formulated.

A mathematics Ph.D. candidate and teacher educator from the College of Teacher Education reviewed the MAT items to ensure consistency, clarity, and accuracy in the answer key. The review was guided by benchmark criteria, such as the alignment of sample questions with the syllabus and the research objectives. Based on expert feedback and comments, some items were revised prior to the pilot study. Table 2 provides the specifications table for content validity.

Reliability

Reliability is an additional technique for assessing participant consistency and instrument stability. Assessing test-retest reliability is crucial for confirming that measurements remain consistent over time, allowing for reliable comparisons between individuals and different areas of interest (Putnick & Bornstein, 2016). There are different methods for measuring internal consistency, with the most commonly used being Cronbach's alpha coefficient and the Kuder-Richardson KR20 formula (Ntumi et al., 2023).

Forty secondary school students who had learned the identified chapters were chosen from Nekemte town and given the MAT as part of a pilot study. Kuder-Richardson's 20 formula (KR20) was used to calculate the internal reliability coefficient, which came out to be 0.73. Scores of 0.70 and higher are generally regarded as acceptable (Taber, 2017). As a result, it was discovered that the test items used in this study were reliable and valid. The mean difficulty level of MAT (0.36) and its discrimination index (0.38) are also within acceptable ranges after all of these steps were completed; the final version of the test items was given as pre-test and post-tests to assess students' mathematics achievement before and after intervention (Shenoy et al., 2023).

The researchers rated each item using the aforementioned criteria, and then computed the total scores from the MAT. The test has a maximum score of 24 and a minimum score of 0, with its appropriateness scaled to 100.

The researcher also developed a table of specifications outlining the content areas to be assessed. This table was designed to ensure a balanced representation of propositional knowledge from the Grade 10 mathematics curriculum. Table 3 illustrates this specification table, highlighting the distribution of content areas.

Table 3
Specification for Mathematics Achievement Test

Chapters of G10	Contents	Number of Items
Chapter 1	Relations and Function	7
Chapter 2	Polynomial Functions	9
Chapter 3	Exponential and Logarithmic Functions	8

The existing literature uses a variety of approaches to evaluate the test item. The researcher used equal weighting, which is the most common approach in which each correct response earns the same value, typically one point. Incorrect responses receive zero points, regardless of the difficulty level of the item.

The teaching content for both the EG and the CG focused on key mathematical concepts, specifically relations and functions, polynomial functions, and exponential and logarithmic functions. These topics were chosen for their fundamental role in the study of advanced mathematics and their relevance to students' overall mathematical development. In both groups, the same content was covered, but the delivery methods differed: the EH engaged with these topics through a BL model with lab rotation using Google Classroom, while the CG received instruction through conventional, face-to-face teaching methods. This ensured that the two groups were exposed to the same core material, allowing for a valid comparison of how different educational approaches influenced students' understanding and achievement in these areas of mathematics.

The facilitation of the CG and the EG in this study involved different educational approaches, which were crucial to the comparison of the two learning models. In the CG, the teacher followed conventional methods of instruction, primarily focusing on direct face-to-face teaching, lectures, and textbook exercises. Students were taught in a conventional classroom setting, with no use of digital tools, and the learning environment emphasized passive learning. The facilitation in this group relied on teacher-led explanations, discussions, and assessments to evaluate student understanding.

In contrast, the EG was facilitated using a BL approach, incorporating a lab rotation model through the use of Google Classroom. This approach combined face-to-face instruction model with online resources, where students had access to multimedia content such as videos, interactive exercises, and assignments in Google Classroom. The use of technology allowed for greater flexibility in learning, enabling students to engage with the content at their own pace and access supplementary materials outside of class hours. To make this comparison clearer, a table could be created to visually summarize the different teaching methods, content delivery, and learning environments for both the EG and CG. This would provide a more structured and accessible comparison of how each group was facilitated and how these differences may have impacted their learning outcomes.

PROBLEMS
OF EDUCATION
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Vol. 83, No. 1, 2025

Table 4
Comparison of Teaching Features and Methods between Comparison and Experimental Groups

Method	Comparison Group (CG)	Experimental Group (EG)
Teaching Method	Conventional face-to-face instruction	BL with lab rotation through Google Classroom
Assessment Method	Standardized in-class tests and assignments	face-to-face, Online assignments and interactive assessments via Google Classroom
Teacher's Role	Teacher-centered, direct instructional strategy	Facilitator, guiding students through both online and face-to-face activities

Study Procedures

The research process begins with the clear formulation of a research hypothesis, focusing on the relationships between the independent variable (the educational model) and the dependent variable (achievement). Following this, the researchers purposefully select the two schools who meet specific inclusion criteria. A treatment group consisting of 38 students, along with two mathematics teachers and one paraprofessional teacher assigned to support the EG during online learning, received training. The researchers then administer pre-tests to establish baseline levels of the dependent variable before any intervention. Random selection assigns participants to either the EG or CG. The EG undergoes a 20-week intervention, while the CG learns the same material for the same duration using conventional methods. The program trains EG students to access online educational resources and introduces them to the principles of BL. The researchers used the Google Classroom Learning Management System to create the invitation link for the online learning platform. Before they could log into the system, students needed to create an email account and enter the invitation passcode the researcher provided to join the group classroom.

Students had to use their unique accounts to log in to support continuous learning. The online learning platform is designed specifically to complement conventional in-person instruction, incorporating features such as lesson distribution, feedback collection, quizzes, assignments, and discussion forums. Students can then actively interact with all of the educational content that their teachers have provided via the online interface.

The conventional lecture method was employed in the CG, with the mathematics teacher delivering content through conventional lectures. This approach, typical in Ethiopian secondary schools, involved the teacher presenting subject matter, demonstrating examples, and explaining formulas, while students passively listened and took notes. Notably, this method relied on conventional practices and did not integrate technology-based resources, reflecting a conventional yet widely accepted approach.

Throughout the intervention, both groups undergo progressive testing, which aims to gauge students' incremental improvement and comprehension levels over time, serving as a measure of the intervention's effectiveness. Post-tests are conducted after the intervention period to measure changes in the dependent variable. Moreover, it fosters a culture of continuous learning and adaptation, encouraging students to actively engage with the material and strive for on-going improvement.

Data Collection

The researchers collected the data using a test that assesses students' mathematical achievement. The measuring device aims to capture a comprehensive view of the student's mathematical proficiency, enabling the evaluation of the learning model's effectiveness. The exam specifically assesses students' fundamental knowledge of the identified topics. Students took this exam both before and after, and they implemented the lessons they had learned. The intervention involved administering two progressive tests between the pre-and post-tests. Progressive Test 1 allows for on-going assessment during a learning process, enabling timely feedback and adjustment of educational strategies, while Progressive Test 2 further reinforces learning by building upon the insights gained from Progressive Test 1, culminating in a comprehensive evaluation of student progress from pre-test to post-test.

Data Analysis

Levene's test and normality tests are integral to statistical analysis, ensuring that the assumptions required for parametric tests, such as ANOVA, are met. In this study, the collected data were thoroughly analyzed by comparing the pre-test and post-test results of both assessments to evaluate changes and outcomes effectively. Descriptive statistics were employed to summarize and organize the data, providing a clear and concise overview of its key characteristics, such as central tendencies and variability. To further interpret the data, inferential statistical methods were applied, enabling the researchers to draw meaningful conclusions and make predictions about the broader population based on the sample. Ultimately, the one-way ANOVA was used to test for statistically significant differences between groups, assessing whether the observed variations in outcomes were meaningful within the experimental context.

Ethical Consideration

The researcher obtained formal approval from the university and the education bureau to conduct a study comparing the effectiveness of a BL educational model (specifically lab rotation) with conventional methods in secondary schools. Ethical considerations included informed consent, confidentiality, and participant well-being. The researcher provided the participants with information regarding the study's objectives, their rights, and confidentiality protocols. Leveraging their experience, the researcher built trust with the participants and prioritized their emotional well-being throughout the study. After the study, the researchers held debriefing sessions to discuss any potential emotional effects and offered psychological counseling if necessary, though none of the participants sought it.

Research Results

The effect of a BL educational model, which especially uses lab rotation, on students' academic achievement in comparison to conventional instruction techniques was investigated in this study using Levene's test, and one-way ANOVA analysis.

Table 5
Skewness and Kurtosis, and Levene's Test on pre-test and post-test on MAT

Variables	Group				Levene's test	
		N	*Skewness*		*Kurtosis*	*F*
Pre-Achievement	EG	38	.409	.176	3.170	.079
	CG	45	.026	-.914		
Post-Achievement	EG	38	-.021	-.650	2.396	.126
	CG	45	-.764	.576		

The test aimed to detect a statistically significant difference between the groups' pre- and post-test scores while also verifying the fulfilment of their difference sequence averages. Table 5 displayed the skewness and kurtosis values of the groups, confirming the normalcy of the difference sequences, post-test, and pre-test. The skewness and kurtosis scores for the groups' difference sequences, as well as for the pre-test and post-test, ranged between -1 and +1, indicating a normal distribution (Ramos et al., 2017). Levene's test results indicated that the data achieved homogeneity of variance for the dependent variable in both the pre-test (ρ = .079) and the post-test (ρ = .126). Consequently, the finding implies that there was no violation of any of the assumptions as indicated in Table 5. To verify the assumption of homogeneity of variance, a hypothesis test was employed.

Table 6
Descriptive Statistics of all Groups in Mathematics Achievement

Variables	Group	*N*	*M*	*SD*	*SE*
Pre Achievement test	EG	38	30.55	8.53	1.38
	CG	45	28.15	6.04	1.99
Post Achievement Test	EG	38	50.55	6.72	1.09
	CG	45	35.56	9.59	1.06

The data in Table 6 show that, on average, EG achieved the highest mathematics scores following the intervention. The EG's mean score was M = 50.55 (SD = 6.72), significantly higher than the CG, which had a mean score of M = 35.56 (SD = 9.59). The EG continuously outperformed the CG during the intervention, highlighting the BL strategy's efficacy. However, fluctuations in achievement were observed across all groups from the pre-test to the post-test, reflecting the dynamic nature of mathematical learning. The study emphasizes the importance of adopting effective teaching methodologies, like BL, to promote sustained academic progress in mathematics, particularly in areas such as procedural skills, conceptual understanding, reasoning, and problem-solving.

Table 7
One-way ANOVA Test on All Mathematics Achievement Score

Variables		*SS*	*df*	*MS*	*F*	*p*	η^2
Pre-Achievement	Between Groups	118.712	1	118.712	2.240	.138	.027
	Within Groups	4293.398	81	53.005			
	Total	4412.110	82				
Post-Achievement	Between Groups	4630.696	1	4630.696	65.564	.001	.447
	Within Groups	5720.910	81	70.629			
	Total	10351.607	82				

Research Hypothesis 1: There is a statistically significant difference in post-test mathematics achievement scores between students taught using the BL model and those taught using conventional methods.

The significance of the study is evident in its exploration of mean differences between the EG and CG groups in pre- and post-test achievement scores. For the pre-test, (p =.138), as indicated in Table 7, exceeded the significance inception (=.05), indicating no statistically significant difference in pre-test scores between the groups. This suggests that both groups had comparable baseline in mathematics achievement before the intervention. However, for the post-test, (p =.001<.05) demonstrating a statistically significant difference in post-test scores between the groups. As a result, the significant difference in the mean scores between the EG and CG led to the acceptance of the alternative hypothesis (RHa1). This suggests that the intervention had a measurable effect on the dependent variable, supporting the proposed relationship outlined in the alternative hypothesis.

Research Hypothesis 2: There is a significant effect size (η^2) between the comparison group and experimental group students on the post-MAT.

The effect size, represented by eta squared (η2), underscores the practical significance of the findings. For Pre-Ach, η2=.027 indicates a small effect size, meaning the group differences accounted for only 2.7% of the total variance in Pre-Ach scores. This suggests that prior to the intervention, the two groups were relatively similar in their initial achievement levels. However, for Post-Ach, η2=.447 reflects a large effect size, with the group differences explaining 44.7% of the variance in Post-Ach scores. The significant difference in eta squared between the EG and CG in the post-test led to the acceptance of the alternative hypothesis (RHa2), indicating that the intervention had a measurable effect on mathematics achievement.

Table 8
Paired Sample T-Test for Pre-Test and Post-Test Results on MAT

Group	Variables	Paired differences						
		MD	*SD*	*SEM*	*t*	*df*	*p*	Cohen's *d*
EG	PostAch – preAch	19.999	12.00	1.95	10.27	37	.001	1.01
CG	PostAch – preAch	7.408	10.12	1.51	4.91	44	.003	.12

The results in Table 8 indicate significant improvements in mathematics achievement for both the EG and the CG, as shown by the paired t-tests comparing post-achievement (PostAch) and pre-achievement (PreAch) scores. For the EG, *MD* = 19.999 (*SD* = 12.00, *SEM* = 1.95), with a t=10.27, *df* = 37, and a highly significant *p*-value of .001. This improvement is accompanied by a large effect size (Cohen's *d* = 1.01), suggesting that the BL approach used in the experimental group had a strong positive effect on students' achievement. In contrast, the CG showed a smaller but still statistically significant improvement, with an *MD* = 7.408 (*SD* = 10.12, *SEM* = 1.51), *t*-value of 4.91, *df* = 44, and = .003. However, the effect size was small (Cohen's *d* = .12). Cohen (1988) suggests a minimal effect size, with Cohen's *d* = .12 indicating that the conventional teaching method had a much weaker effect on achievement. These findings suggest that the BL model was substantially more effective in enhancing student achievement compared to the conventional model.

Discussion

The study aimed to assess the effect of BL on secondary school students' academic achievement in mathematics. The results indicated that BL, which integrates in-person and virtual learning, had a statistically significant positive effect on mathematics achievement compared to the conventional teaching method. The analysis showed a notable difference in mean scores between the groups, with $p < .05$, confirming that the difference was unlikely to occur by chance. The use of digital tools and interactive features on platforms like Google Classroom significantly improved students' understanding and achievement in mathematics. BL promotes deeper comprehension of mathematical concepts and the development of adaptable learning strategies, which are essential for modern education by enhancing engagement, personalizing learning, and increasing access to resources.

The study demonstrates how incorporating BL with lab rotation, facilitated by Google Classroom, enhances conventional mathematics teaching methods. This modern approach not only enhances the learning experience but also equips students with essential skills for success in today's dynamic digital landscape. The results confirm the alternative hypothesis, underscoring the significant positive effect of BL with lab rotation via Google Classroom (content, audio, and images) on mathematics achievement compared to conventional methods. This highlights the effectiveness and potential advantages of integrating BL strategies, particularly through lab rotation, to improve mathematics learning outcomes.

By fully utilizing the strengths of each teaching method and integrating the advantages of both online and in-person instruction, teachers and students can achieve the greatest benefits (Tong et al., 2022). This study promoted flexibility and decreased the workload of instructors by using online submissions to supplement in-person education. Previous research supports these advantages, indicating that effective learning strategies consistently lead to successful learners and the impact of teacher-student relationships on academic excellence (Jamaluddin et al., 2021).

The BL model encourages greater participation from students in the educational process. BL enables students to study at their own pace and according to their individual schedules, accommodating various learning styles and timelines (Balolong, 2022). Students who participated in BL courses achieved higher academic performance compared to those who attended conventional classes (Tong et al., 2022). The results of this investigation also supported those of other studies (Çiftçi, 2020), which discovered data demonstrating the superiority of BL over conventional methods in terms of academic achievement.

The study shows that using the Google Classroom platform in the lab significantly boosts students' mathematics achievement. This suggests that integrating Google Classroom into the learning environment can enhance students' performance in mathematics, a conclusion supported by research from Egara and Mosimege (2024) and Sasmita et al. (2021), which found that Google Classroom positively influenced students' attitudes and academic success in secondary schools. This effect may be linked to students' preference for technology driven teaching tools, which can increase their interest and active participation in mathematics lessons. Consequently, higher engagement with the material may lead to better concept retention and, ultimately, improved academic performance in mathematics

However, the results of this study are inconsistent with several other studies, such as Alsalhi et al. (2021), which examined the effect of BL on students' academic performance in science and mathematics and found no significant difference between the EG and CG post-test scores. Additionally, research by Kundu et al. (2021) revealed mixed results regarding the effectiveness of BL compared to conventional methods in promoting academic achievement. Despite these discrepancies, Google Classroom's user-friendly interface allows teachers to organize and present resources such as documents, presentations, videos, and links, which could contribute to a more engaging and structured learning experience for students.

Recent research has shown that BL notably enhances students' performance in mathematics. This approach merges interactive online tools with conventional teaching methods, facilitating personalized learning experiences that accommodate different learning speeds and styles. The engaging nature of the online components is vital for maintaining student interest, which is essential for grasping complex mathematical concepts. Furthermore, online platforms frequently offer immediate feedback on assignments and quizzes, enabling students to quickly recognize and address their errors, ultimately improving their performance. Supporting evidence suggests that students in BL environments typically achieve higher scores on standardized tests and other assessments compared to their counterparts in conventional classrooms.

Conclusions and Implications

From the findings, the researchers have reached specific conclusions regarding the effect of the BL educational model in enhancing mathematics achievement in comparison to the conventional model: First, the study validated its findings, revealing statistically significant differences in the mean scores between the groups for the mathematical achievement post-test. This represents the absolute difference between the mean values observed in two different groups in the study. Second, the study's results showed that there were big differences between the groups after the intervention. This means that the intervention had a big effect and explained 44.7% of the differences between the groups. External influences or other factors might account for the remaining 55.3% of the variance that remains unexplained.

The research on the effect of a BL educational model on secondary school students' mathematics achievement holds significant educational and practical value. Its findings demonstrate that blending conventional teaching methods with digital learning platforms can substantially improve students' mathematics performance. This meaningful shift suggests that BL offers an engaging, interactive, and personalized approach to education, addressing diverse learning needs and fostering deeper conceptual understanding. It matters because mathematics is a foundational subject critical for students' academic and professional success, and finding effective teaching methods to enhance achievement in this area can bridge learning gaps, improve equity, and better prepare students for future challenges. Furthermore, the study provides empirical evidence to inform educational policies and practices, encouraging the integration of innovative models like BL into curricula, especially in resource-constrained settings where access to quality education is often limited.

The novelty of this study lies in its integration of the BL model with the lab rotation approach using Google Classroom to boost mathematics achievement an approach not widely explored. By demonstrating its effectiveness in promoting active learning, engagement, and improved academic performance, the study offers fresh insights into the application of digital tools within conventional classroom settings. This work contributes to the existing body of knowledge by presenting a practical and scalable BL framework that aligns with current educational needs.

Limitation

This study has several limitations worth noting. The sample size and context were confined to specific schools and grade levels, which may affect the generalizability of the findings. Furthermore, the use of quasi-experimental methods, while effective, may not completely control for potential confounding variables. Despite these constraints, the study underscores the effectiveness of BL with lab rotation, particularly via Google Classroom, in enhancing mathematics achievement. It provides valuable insights into integrating digital tools with conventional teaching methods, offering a practical framework for educators seeking to modernize their approach. By bridging technology and pedagogy, the research highlights BL's potential to promote active learning, engagement, and independent knowledge construction, which are crucial for addressing the challenges of contemporary education.

Implication

The findings of this study hold significant educational implications for future research on the impact of BL on students' mathematics achievement. Firstly, the results offer valuable guidance for developing and refining multimedia tools designed to support BL environments. Secondly, they highlight the importance of conducting additional quasi-experimental and descriptive studies to explore both the advantages and challenges associated with implementing BL in secondary education. Thirdly, the findings underscore that integrating an online model within a BL framework, such as through Google Classroom; can enhance student achievement, engagement, and active learning by fostering knowledge construction rather than passive learning. Furthermore, there is a need for contemporary studies to identify effective BL approaches in secondary schools to optimize academic performance. Lastly, the study suggests that BL promotes independent learning, enabling students to deepen their understanding of subjects like mathematics beyond the limitations of conventional classroom settings

Recommendations

Considering the study's findings, the researchers propose the following recommendations: 1) Utilizing Google Classroom for teaching mathematics in secondary schools is recommended. The government should allocate resources to public schools to improve facilities that support the use of Google Classroom for teaching. 2) This research is not widely conducted in many countries, in particular Ethiopia. Further studies are needed to investigate the effects of platforms like Google Classroom on various subjects. 3) Moreover, it's suggested to prioritize blending in-person and online instruction professionally, as this hybrid approach can maximize learning outcomes by combining the strengths of both methods.

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Availability of Data and Materials

The datasets generated and/or analyzed during this study are not publicly accessible because they contain personal participant information that cannot be shared openly. However, interested researchers can obtain these datasets by contacting the corresponding author and making a reasonable request. This ensures that any sharing of data maintains the privacy and confidentiality of the participants involved in the study. The data supporting the findings of this study are available from the corresponding author, Dinkissa, and can be requested via the institutional email at dinkisagofar1@gmail.com

Declaration of Interest

The authors declare no competing interest.

References

Alsalhi, N. R., Al-Qatawneh, S., Eltahir, M., & Aqel, K. (2021). Does blended learning improve the academic achievement of undergraduate students in the mathematics course? A case study in higher education. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(4), Article 1951. https://doi.org/10.29333/ejmste/10781

Balolong, M. (2022). Challenges of blended learning: A phenomenological Inquiry. *Social Science Research Network*. https://doi.org/10.2139/ssrn.4103847

Bart, R., Olney, T., Nichols, M., & Herodotou, C. (2019). Effective usage of learning analytics: What do practitioners want and where should distance learning institutions be going? *Open Learning*, *35*(2), 178–195. https://doi.org/10.1080/02680513.2019.1690441

Becker, S. P., Leopold, D. R., Burns, G. L., Jarrett, M. A., Langberg, J. M., Marshall, S. A., McBurnett, K., Waschbusch, D. A., & Willcutt, E. G. (2016). The internal, external, and diagnostic Validity of Sluggish Cognitive Tempo: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry*, *55*(3), 163–178. https://doi.org/10.1016/j.jaac.2015.12.006

Beyessa, F. (2014). Major factors that affect grade 10 students' academic achievement in science education at Ilu Ababora General Secondary of Oromia Regional State, Ethiopia. *International Letters of Social and Humanistic Sciences, 32,* 118–134. https://doi.org/10.18052/www.scipress.com/ilshs.32.118

Çiftçi, B. (2020). The effect of blended learning on academic achievement and attitudes at social studies courses. *Open Journal for Educational Research*, *4*(2), 143–150. https://doi.org/10.32591/coas.ojer.0402.05143c

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum

Egara, F. O., & Mosimege, M. (2024). Effect of blended learning approach on secondary school learners' mathematics achievement and retention. *Education and Information Technologies, 29,* Article 12651. https://doi.org/10.1007/s10639-024-12651-w

Faturoti, B. (2022). Online learning during COVID19 and beyond: A human right based approach to internet access in Africa. *International Review of Law Computers & Technology*, *36*(1), 68–90. https://doi.org/10.1080/13600869.2022.2030027

Graham, C. R. (2009). Blended learning models. *In IGI Global eBooks* (pp. 375–382). https://doi.org/10.4018/978-1-60566-026-4.ch063

Halverson, L. R., Graham, C. R., Spring, K. J., Drysdale, J. S., & Henrie, C. R. (2014). A thematic analysis of the most highly cited scholarship in the first decade of blended learning research. *The Internet and Higher Education*, *20*, 20–34. https://doi.org/10.1016/j.iheduc.2013.09.004

Hermino, A., & Arifin, I. (2020). Contextual character education for students in senior high school. *European Journal of Educational Research, 9*(3), 1009–1023. https://doi.org/10.12973/eu-jer.9.3.1009

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

Jamaluddin, N. S., Kadir, S. A., Alias, S. N., & Abdullah, A. (2021). A review of psychosocial learning environment. *International Journal of Academic Research in Progressive Education and Development, 10*(3). https://doi.org/10.6007/ijarped/v10-i3/11189

Kundu, A., Bej, T., & Dey, K. N. (2021). Time to achieve: Implementing blended learning routines in an Indian elementary classroom. *Journal of Educational Technology Systems*, *49*(4), 405–431. https://doi.org/10.1177/0047239520984406

Lazar, I. M., Panisoara, G., & Panisoara, I. O. (2020). Digital technology adoption scale in the blended learning context in higher education: Development, validation and testing of a specific tool. *PloS One, 15*(7), Article e0235957. https://doi.org/10.1371/journal.pone.0235957

Lamas, H. (2015). School performance review. *Journal of Educational Psychology, 3*(1), Article 35. https://doi.org/10.20511/pyr2015.v3n1.74

Lindner, K., & Schwab, S. (2020). Differentiation and individualization in inclusive education: a systematic review and narrative synthesis. *International Journal of Inclusive Education*, 1–21. https://doi.org/10.1080/13603116.2020.1813450

Luo, Y. (2021). The opportunities and limitations of blended learning and the flipped classroom for second language teaching. *BCP Social Sciences & Humanities*, *14*, 190–194. https://doi.org/10.54691/bcpssh.v14i.193

Macharia, J. M. (2022). Systematic literature review of interventions supported by integration of ict in education to improve learners' academic performance in stem subjects in Kenya. *Journal of Education and Practice*, *6*(3), 52–75. https://doi.org/10.47941/jep.979

Ministry of Education [MOE]. (2017). *Strategic Policy for National Science, Technology and Mathematics Education*. http://www.moe.gov.et

NEAEA. (2014). *Early grade mathematics assessment (EGMA) in Ethiopia: Baseline study report*. Addis Ababa, Ethiopia.

Nikolopoulou, K. (2022). Face-to-face, online and hybrid education: University students' opinions and preferences. *Journal of Digital Educational Technology, 2*(2), *Article ep2206.* https://doi.org/10.30935/jdet/12384

Ntumi, S., Agbenyo, S., & Bulala, T. (2023). Estimating the psychometric properties (item difficulty, discrimination, and reliability indices) of test items using Kuder-Richardson approach (KR-20). *Shanlax International Journal of Education*, *11*(3), 18–28. https://doi.org/10.34293/education.v11i3.6081

Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, *41*, 71–90. https://doi.org/10.1016/j.dr.2016.06.004

Ramos, C., Costa, P. A., Rudnicki, T., Marôco, A. L., Leal, I., Guimarães, R., Fougo, J. L., & Tedeschi, R. G. (2017). The effectiveness of a group intervention to facilitate posttraumatic growth among women with breast cancer. *Psycho-Oncology, 27*(1), 258–264. https://doi.org/10.1002/pon.450

Samat, M. F., Awang, N. A., Hussin, S. N. A., & Nawi, F. A. M. (2020). Online distance learning amidst COVID-19 pandemic among university students. *Asian Journal of University Education, 16*(3), Article 220. https://doi.org/10.24191/ajue.v16i3.9787

Sasmita, N. K. S., Redhana, I. W., & Suja, I. W. (2021). The effect of online learning on students' learning achievement on colloid concept. In *First International Conference on Science, Technology, Engineering and Industrial Revolution (ICSTEIR 2020)* (pp. 357–360). Atlantis Press.

Shenoy, V., Ravi, P., & Chandy, D. (2023). A cross-sectional study on item analysis of prevalidated and nonvalidated anatomy multiple-choice questions. *National Journal of Clinical Anatomy*, *12*(2), Article 94. https://doi.org/10.4103/njca.njca_9_23

Singh, J., Steele, K., & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, and post-pandemic world. *Journal of Educational Technology Systems, 50*(2), 140–171. https://doi.org/10.1177/0047239521104786

Singhal, D. (2017). Understanding student-centered learning and philosophies of teaching practices. *International Journal of Scientific Research and Management, 5*(2), Article v5i2.02. https://doi.org/10.18535/ijsrm/v5i2.02

Syahrawati, N. E. Y., Susantini, N. E., & Indana, N. S. (2022). Profile of blended learning implementation in learning activities. *International Journal of Online and Remote Education Research*, *3*(1), 45–60. https://doi.org/10.46245/ijorer.v3i1.183

Taber, K. S. (2017). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tesfa, M. (2014). *The validity of university entrance examination and secondary school grade point average for predicting first-year university students' academic performance*. University of Twente. https://essay.utwente.nl/66652

Tong, D. H., Uyen, B. P., & Ngan, L. K. (2022). The effectiveness of blended learning on students' academic achievement, self-study skills and learning attitudes: A quasi-experiment study in teaching the conventions for coordinates in the plane. *Heliyon*, *8*(12), Article e12657. https://doi.org/10.1016/j.heliyon.2022.e12657

Tongco, M. D. C. (2007). Purposive sampling as a tool for informant selection. *Ethnobotany Research and Applications, 5*, 147–158. https://doi.org/10.17348/era.5.0.147-158

Zhang, W., Chen, W., Wang, R., Zhao, H., Yuan, E., & Wang, Z. (2020). The presence design of online teaching based on the CoI model. In *2020 IEEE 2nd International Conference on Computer Science and Educational Informatization (CSEI)* (225–229). IEEE.

Woldetsadik, G., & Bank, T. W. (2013). *National learning assessment in Ethiopia: Sharing experiences and lessons*. The World Bank.

Appendix A: Mathematics Achievement Test (Pretest and Posttest)

Instruction: This test consists of 24 multiple-choice questions from grade 10 mathematics students' textbook topics. Each question has four options. Attempt all questions and choose the correct answer among the given alternatives and write the letter of your choice on the space provided. 1 point each

______ 1. If $B = \{-2, -1, 0, 1, 2\}$ and $A = \{x + y : x \in B \text{ and } y \in B\}$, then the list of all elements of A is:

A. {-3, -1, 0, 1, 3} C. {-4, -3,-2, -1, 0, 1, 2, 3, 4}
B. {-3, -2, -1, 0, 1, 2, 3} D. {-2, -1, 0, 1, 2}

______2. Let $D = \{0,1,2,4\}$ and $R = \{(x, y) : x, y \in D \text{ and } y < x\}$. From the following ordered pairs which one belongs to R?

A. (1,3) C. (2,0)
B. (-1,1) D.(1,2)

______3. A relation that has no two ordered pairs with identical first coordinates while having different second coordinates is called ________________

A. Domain C. Function
B. Range D. Inverse function

______4. Let $f(x) = x - 2$ and $g(x) = x^2 + 3x - 7$ be two functions. Then evaluate $\left(\frac{g}{f}\right)(-1)$.

A. $\frac{1}{3}$ C. $-\frac{1}{3}$
B. 3 D. -3

______ 5. If $f(x) = 3x - 3$ and $g(x) = 2 - 3x$, then $(2f + 3g)(x)$ is equal to

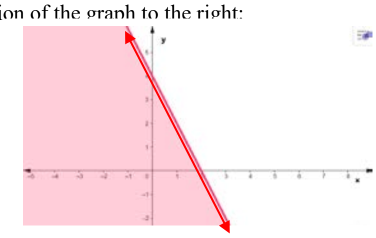
A. 12x+6 C. -6x+5
B. -3x D. $-9x^2+15x-6$

______ 6. Given the function f = {(1, 0), (-1, 2), (3, 4), (2, 1)} and
g = {(0, 0), (2, 3), (3, -1), (1, -1)},
then, which one of the following is true?

A. (f.g)(2) = -1 C. 2f(2) = 2g(1)
B. (f-g)(3) = 5 D. (f+g)(-1) = 1

______ 7. Which inequality represents the shaded region of the graph to the right:

A. $\{(x, y) : y \leq -2x + 4\}$
B. $\{(x, y) : y < -2x + 4\}$
C. $\{(x, y) : y \geq -2x + 4\}$
D. $\{(x, y) : y > -2x + 4\}$



______8. After rewriting the polynomial $2-11x^2-8x+6x^2$ in the standard form, what are the respective simplified forms and the name of this polynomial?

A. $5x^2-8x-2$, quadratic trinomial C. $-6x^2-8x-2$, cubic polynomial
B. $-5x^2-8x+2$, quadratic trinomial D. $6x^2-8x+2$. Cubic trinomial

______9. If the degree of a polynomial function f(x) is 'n' for n is the set of whole numbers, then which of the following is not true about polynomial function f(x)?

A. f(x) has at most n roots. C. f(x) crosses the x-axis at most n times.
B. f(x) may not cross the x-axis D. f(x) has n-1 number of turning point

______10. A polynomial function p is given by $p(x) = \frac{3x^3-4x^5+x^2-6x+1}{12} + \frac{x}{2} - x^4$. From the following statements which one is true about p?

A. In p(x), the coefficient of x is 0. C. The constant term is $\left(-\frac{1}{2}\right)$.
B. The degree of p(x) is 3. D. The leading coefficient is $\frac{1}{4}$

______11. Which of the following is true about $f(x)= x^4-4x^3+x^2+6x$, given that -1 and 0 are the zeros of f(x)?

A. f(x)=0 has exactly two zeros C. The graph of f(x) = y has exactly two x-intercepts.
B. f(x)>0 has no solution D. f(x)=0 has exactly four distinct zeros

______12. Suppose $f(x) = x^2 + 3$ and $g(x) = x - 2$. Which of the following is a formula for (f − g) (x)?

A. $(f - g)(x) = x^2 - x + 1$ C. $(f - g)(x) = x^2 - 4x + 7$
B. $(f - g)(x) = x^3 + 2x^2 + 3x - 2$ D. $(f - g)(x) = x^2 - x + 5$

______13. Let f(x) be a polynomial function of degree greater than or equal to one. Which one of the following statements correctly describes the remainder theorem by using f(x)?

A. If x-c is a factor of f(x), then f(c)=0 for a constant c.
B. For the real number c, if f(x) is divided by x-c, the remainder is f(c).
C. If f(c)=0, then x-c is the factor of f(x) for a constant c.
D. For the real number c, if f(x) is divided by x-c, the remainder is f(c)=0.

______ 14. From the following pairs of numbers, which one represents the rational zeros of the polynomial $f(x) = x^4 - x^3 - 4x^2 + 4x$?

A. -1 and 3 | C. -1 and -3
B. -4 and -1 | D. -2 and 2

______ 15. If f and g are polynomial functions of degree 4, then which of the following is necessarily true?

A. f + g is of degree 8 | C. 2g is of degree 8
B. f + g is of degree 4 | D. f.g is of degree 8

______ 16. If a polynomial function $p(x) = ax^3-4x^2-1$ is divided by x+1, the remainder is -1, then the value of "a" is ______

A. -2 | C. -4
B. 4 | D. 2

_______ 17. If m and n are positive integers which of the following is equal to m^{n^2}?

A. $(m^n)^2$ | C. m^n+m^n
B. $(m^n)^n$ | D. $m^n.m^n$

______ 18. On question number 12, let $f(x) = (3)^x$ and $g(x)=\left(\frac{1}{3}\right)^x$ then which one of the following is true about these functions?

A. For x<0, the graph of f(x) lays above the graph of g(x).
B. For x≥0, the graph of f(x) lays above the graph of g(x).
C. For x>0, both graphs f(x) and g(x) lay below the line y=1.
D. For x<0, both graphs f(x) and g(x) lay below the line y=1.

______ 19. For x, y is positive real numbers, $\log_5 x^5y^2$ is equal to:

A. $5\log_5 x + 2\log_5 y$ | C. $\log x^2 + \log y^5$
B. $2\log_5 x + 5\log_5 y$ | D. $\log_5 x^5 . \log_5 y^2$

______ 20. Which expression is equivalent to $4 + \log_2 x$?

A. $\log_2(2x)$ | C. $4\log_2(2x)$
B. $\log_2(16 + x)$ | D. $\log_2(16x)$

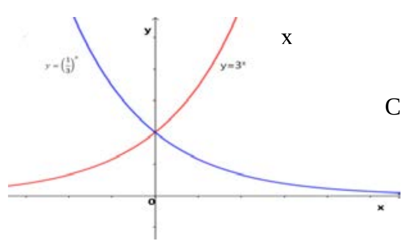
______ 21. If log2=0.3010 and log3=0.4771, which one of the following is the value of $log\ 12$?

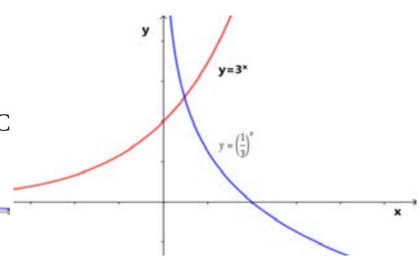
A. 0.9542 | C. 0.6020
B. 1.0791 | D. 1.2552

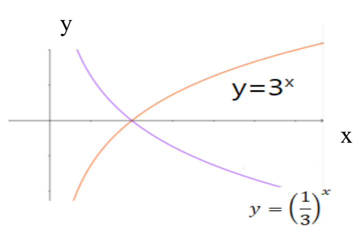
______ 22. Which one of the following is considered as an exponential expression?

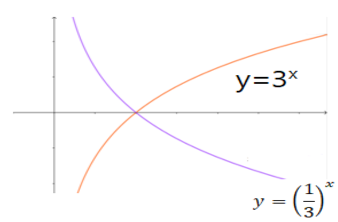
A. $3x^2+x+5$ | C. 3^x+5^x
B. 5^x+6x-1 | D. $\sqrt{x^2+8}$

______ 23. From the following sketches drawn on the same coordinate plane, which pair looks like the graphs of both $y = 3^x$ and $y = \left(\frac{1}{3}\right)^x$?

A


C


B


D


______ 24. Let b >1 be a real number, $f(x) = \log_b x$ and $g(x) = \log_{\frac{1}{b}} x$. Which of the following statements is true?

A. $For\ 0 < x < 1, g(x) > 0$ | C. $For\ x > 1, f(x) < 1$
B. $For\ 0 < x < 1, f(x) > 0$ | D. $For\ x > 1, 0 < g(x) < 1$

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