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Blended Learning in Secondary Mathematics: Effects on Student Achievement and Knowledge Retention

Rommel AlAli[1], Yousef Wardat[2], Khaled Al-Saud[3] and Kamal Aldeen Alhayek[4]

Abstract

This study explores the implementation of blended learning in high school mathematics education in Jordan. The primary objective is to develop a structured framework that integrates traditional classroom methods with digital learning tools to create a more dynamic and effective learning environment. Using a quasi-experimental design, this research evaluates the effectiveness of blended learning strategies in enhancing student understanding, engagement, and retention in mathematics. A sample of high school students from a single institution in Jordan was divided into experimental and control groups, with the former utilizing blended learning techniques and the latter following conventional teaching methods. The results demonstrate significant improvements in the mathematics achievement and retention rates of students in the blended learning group compared to the control group. The study also identifies key components and best practices for successful implementation, offering practical recommendations for educators and policymakers. These findings highlight the potential of blended learning to transform mathematics education by catering to diverse student needs and fostering a more engaging and personalized learning experience.

Keywords: *Blended Learning, Student Engagement, Academic Achievement, Retention Rates, Teaching Strategies, Digital Learning Tools*

INTRODUCTION

Blended learning merges traditional in-person classroom techniques with online educational materials and interactive learning opportunities. This approach has garnered significant attention due to its ability to offer a more flexible and personalized learning experience (Luo, 2021; Minaz & Melanie, 2019). In high school mathematics, blended learning can cater to diverse student needs, enhance engagement, and improve learning outcomes. By integrating digital tools and resources with conventional teaching methods, educators can create a more dynamic and interactive learning environment that addresses various learning styles and paces of students (Lin, Tseng, & Chiang, 2017; Mozelius & Hettiarachchi, 2017).

While the exact definition of blended learning remains a topic of discussion (Graham, 2013), it generally includes the integration of in-person and online education. Singh (2003) defined blended learning as a combination of various delivery methods intended to enhance both traditional classroom and online teaching, fostering "learning and the application of learned behaviors." Thorne (2003) described it as a strategy for addressing the challenges of customizing education to individual needs by incorporating innovative and technological advancements. Dziuban, Hartman, and Moskal (2004) suggested considering it a teaching method that combines the benefits and social aspects of in-person classes with the engaging, technology-driven learning opportunities of online environments. Typically, blended learning makes extensive use of educational technologies, merging physical and digital spaces to augment conventional face-to-face instruction.

Blended learning has broadened opportunities for students, enabling learning through various mediums and at different times (White & Geer, 2010), thus enhancing student flexibility. According to Brown (2003), the blended learning environment merges the benefits of e-learning, such as efficiency in time and convenience of location, with the advantages of face-to-face interactions, including personal understanding and motivation. This model also offers greater personalization, giving learners more control over which activities they engage in and for how long. In-person classes help build social presence or 'social comfort,' which is harder and often

[1]King Faisal University, Al-Ahsa, Saudi Arabia; E-mail: ralali@kfu.edu.sa

[2] Higher Colleges of Technology, Abu Dhabi, UAE; E-mail: yousef_alwardat@yahoo.com

[3] Professor of Design and, Experimentation with Artistic Materials, Department of Art Education, King Faisal University; E-mail: Kmsoud@kfu.edu.sa
[4] College of Business Administration, Mutah University

slower to establish in a completely online setting. This hybrid approach facilitates learners' comfort in interacting with peers online and exchanging ideas and resources, thereby deepening their understanding (Mukhtaramkhon, 2022; Mosimege & Egara, 2022).

Blended learning also offers advantages to educators (Drysdale, Graham, Spring, & Halverson, 2013) by enabling them to primarily conduct face-to-face classes while enhancing their proficiency in the online environment. However, the needs of educators are sometimes neglected. Teachers require both time and the support of more experienced colleagues to gain confidence and competence with these tools (Peralta & Costa, 2007) before they can create pedagogically effective e-learning materials. Moreover, developing online mathematics materials demands more time initially, though this effort can be worthwhile in the long run (Ahmad, Shafie, & Janier, 2008). Despite this, teaching practices must adapt to fully leverage the many benefits of flexible learning (Makkar & Sharma, 2021; Mutange, 2020).

Drysdale, Graham, Spring, and Halverson (2013), in their review of dissertations on blended learning, observed a lack of research in K-12 education, especially in the area of K-12 mathematics education, highlighting the necessity for additional studies. Additionally, AlAli and Wardat (2024) emphasized the importance of addressing educational wastage through digital transformation, which is crucial for improving educational outcomes.

The primary purpose of this study is to develop a structured framework for implementing blended learning in high school mathematics education in Jordan. This research seeks to identify the essential components that constitute an effective blended learning environment for mathematics instruction. By pinpointing these critical elements, the study aims to provide a comprehensive understanding of what makes a successful blended learning model (Nworgu, 2003; Nzeadibe et al., 2023; Nzeadibe et al., 2020). Furthermore, addressing factors that contribute to low PISA performance and exploring the integration of generative AI in education (AlAli & Wardat, 2024), as well as evaluating STEM-aligned teaching practices for gifted students (AlAli, Wardat, Saleh, & Alshraifin, 2024), can offer valuable insights for enhancing mathematics education.

STUDY PURPOSE

The primary purpose of this study is to develop a structured framework for implementing blended learning in high school mathematics education in Jordan. This research seeks to identify the essential components that constitute an effective blended learning environment for mathematics instruction. By pinpointing these critical elements, the study aims to provide a comprehensive understanding of what makes a successful blended learning model.

Additionally, the study evaluates the effectiveness of blended learning strategies in enhancing student understanding, engagement, and retention in mathematics. Through a rigorous assessment, it aims to determine how blended learning impacts student performance and engagement compared to traditional teaching methods.

Finally, the study provides practical recommendations for educators and policymakers to facilitate the adoption and integration of blended learning in high school mathematics curricula. These guidelines are intended to help implement blended learning in a way that maximizes its benefits, thereby enhancing the overall quality of mathematics education and making it more dynamic, interactive, and tailored to the diverse needs of students.

STUDY SIGNIFICANCE

The significance of this study is in its potential to transform the teaching and learning of mathematics in Jordanian high schools. By integrating blended learning, educators can create more dynamic and interactive educational experiences that cater to the diverse learning styles and paces of students. This approach not only promotes the development of critical thinking and problem-solving skills but also prepares students for the demands of higher education and the modern workforce.

Blended learning merges the benefits of traditional face-to-face instruction with the flexibility and personalized approach of online learning. This hybrid model effectively addresses the varied needs of students, offering them multiple pathways to grasp complex mathematical concepts. Utilizing technology, educators can provide a more tailored learning experience, enabling students to engage more profoundly with the material and enhance their overall academic performance.

Additionally, the findings of this study can inform policy decisions and educational practices, contributing to the overall improvement of mathematics education in Jordan. The insights gained from this research can help shape teacher training programs, curriculum development, and the implementation of educational technologies. Ultimately, this study aims to enhance the quality of mathematics education, ensuring that students are better equipped with the skills and knowledge they need to succeed in an increasingly digital and interconnected world.

RESEARCH QUESTIONS

What are the essential components of a blended learning environment for teaching mathematics to high school students in Jordan?

How effective are blended learning strategies in enhancing student understanding and engagement in mathematics compared to traditional teaching methods?

What are the perceptions of students and teachers regarding the use of blended learning in high school mathematics education?

THEORETICAL FRAMEWORK

The theoretical framework for this study is based on constructivist learning theory and the Technology Acceptance Model (TAM). Constructivist learning theory, developed by theorists such as Piaget and Vygotsky, asserts that learners construct knowledge through meaningful interactions with their environment and experiences. This theory highlights the importance of active, student-centered learning, where students participate in activities that foster critical thinking, problem-solving, and knowledge application. Within the realm of blended learning, constructivist principles advocate for the fusion of traditional classroom methods with digital tools to cultivate a dynamic and interactive educational environment.

Blended learning is well-aligned with constructivist theory because it offers a variety of instructional methods tailored to different learning styles. By integrating face-to-face instruction with online learning, students can engage with the material in multiple ways, enhancing their understanding and retention. This approach motivates students to take an active role in their learning journey, thereby promoting the development of higher-order thinking skills.

Additionally, the Technology Acceptance Model (TAM) will be used to understand educators' and students' perceptions and acceptance of blended learning technologies. TAM, developed by Davis (1989), is a widely used framework for predicting and explaining user behavior towards new technologies. The model suggests that perceived usefulness and perceived ease of use are the primary factors influencing users' acceptance of technology. In this study, TAM will help to assess how these factors impact the willingness of teachers and students to adopt blended learning in high school mathematics education.

his study aims to provide a comprehensive understanding of the pedagogical and technological aspects of implementing blended learning in mathematics instruction. This dual-framework approach will guide the development of effective strategies for enhancing student engagement, improving academic performance, and overcoming the challenges associated with blended learning in the educational context of Jordan.

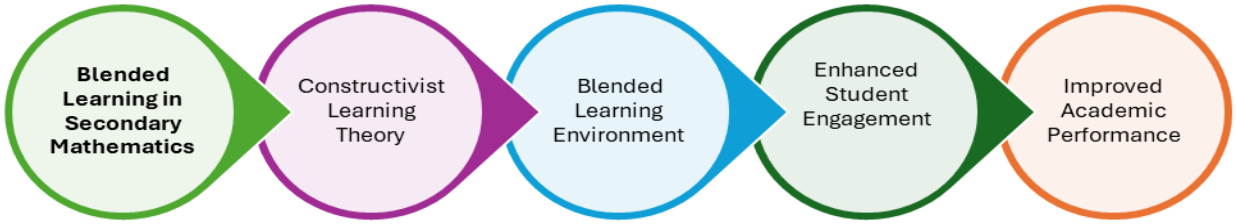

Figure 1: conceptual framework Blended Learning in Secondary Mathematics

LITERATURE REVIEW

IMPACT OF BLENDED LEARNING ON STUDENT ACHIEVEMENT

Various studies have demonstrated the effectiveness of blended learning strategies in boosting student performance in different settings. For example, Indrapangastuti et al. (2021) conducted research in Malaysia to assess the impact of blended learning on secondary school students' trigonometry achievement. Using a quasi-experimental design with 60 participants and t-tests for analysis, they discovered that students in the experimental group outperformed those in the control group. Similarly, Makkar and Sharma (2021) examined the effect of blended learning on the mathematics achievement of ninth-grade students in Amritsar, India. Their quasi-experimental study and t-test analysis showed significant improvement in the experimental group's performance.

In another study, Tong et al. (2022) evaluated the effectiveness of blended learning on tenth-grade students' mathematics achievement in Vietnam. With a sample of 96 students and t-tests for statistical analysis, they found that the blended learning approach significantly enhanced students' mathematics performance. Furthermore, Lin et al. (2017) investigated the impact of blended learning on junior secondary students' mathematics achievement in Taiwan. Using ANCOVA for statistical analysis with 54 students, their study indicated that the blended learning method effectively improved mathematics achievement, with male students making greater gains than female students.

BLENDED LEARNING AND RETENTION

Blended learning has also been shown to have a positive impact on student retention. Awosdeyi et al. (2014) examined the influence of blended learning on university students' achievement in pre-algebra in Nigeria. Utilizing a pretest-posttest randomized experimental design and ANCOVA, the study found that blended learning significantly enhanced students' achievement and retention compared to traditional teaching methods. Similarly, Sivakumar and Selvakumar (2019) investigated the effectiveness of blended learning in improving physics achievement and retention among higher secondary students in India. Their quasi-experimental study, which included 40 students, demonstrated significant improvements in performance and retention for those in the experimental group, with no notable gender differences.

In the United States, Minaz and Melanie (2019) used a non-experimental quantitative comparative research design to explore the impact of the station rotation model of blended learning on the math achievement of

sixth-grade students. Involving 413 students, their research indicated that blended learning resulted in higher scores for the experimental group, showcasing its effectiveness in promoting academic growth, particularly for students who require additional support.

CHALLENGES IN MATHEMATICS EDUCATION

Despite these positive findings, challenges in mathematics education persist, particularly in secondary schools. Okeke et al. (2023a, 2023b) and Osakwe et al. (2023) highlighted ongoing struggles with poor mathematics performance among students in Uzo-Uwani LGA, Enugu State, Nigeria. This issue is further supported by broader concerns about low mathematics proficiency among Nigerian learners, as noted by Azuka (2012) and Badru and Saka (2021). Addressing these challenges requires a closer examination of the impact of blended learning on mathematics achievement and retention in this context.

GENDER AND BLENDED LEARNING

Studies have shown mixed results regarding gender differences in the effectiveness of blended learning. While Lin et al. (2017) reported greater gains for male students in Taiwan, Awosdeyi et al. (2014) and Sivakumar and Selvakumar (2019) found no significant gender differences in Nigeria and India, respectively. This study aims to further explore the impact of gender on the effectiveness of blended learning in mathematics education in Nigeria.

METHODOLOGY

RESEARCH DESIGN

This study employs a quasi-experimental design to evaluate the impact of blended learning on high school students' mathematics achievement and retention. The quasi-experimental design is chosen because it allows for the comparison of groups with some level of control over variables, even though random assignment is not feasible. The study involves two groups: an experimental group that receives blended learning instruction and a control group that receives traditional face-to-face instruction.

PARTICIPANTS

The study involves a sample of 120 high school students from a single high school in Jordan. These students are divided into two groups: 60 students in the experimental group and 60 students in the control group. Participants are selected through purposive sampling to ensure the sample accurately represents the population in terms of gender, age, and academic ability. This approach allows for a comprehensive examination of the effects of blended learning on diverse student demographics.

INSTRUMENTS

To collect data, the study utilizes the following instruments:

Mathematics Achievement Test (MAT): A standardized test designed to assess students' understanding and proficiency in mathematics. The test covers key areas of the high school mathematics curriculum and includes multiple-choice and open-ended questions.

Retention Test: A follow-up test administered four weeks after the post-test to evaluate the retention of mathematical concepts learned during the intervention period.

Questionnaires: Surveys administered to both students and teachers to gather qualitative data on their perceptions of blended learning and its impact on the learning process.

PROCEDURE

The study follows a structured procedure over a period of ten weeks:

Pre-test: Both the experimental and control groups take the Mathematics Achievement Test (MAT) in the first week to establish a baseline for comparison.

Intervention: For the next four weeks, the experimental group receives blended learning instruction, combining traditional classroom teaching with online educational materials and interactive learning opportunities. The control group continues with traditional face-to-face instruction.

Post-test: In the sixth week, both groups take the MAT again to assess the immediate impact of the blended learning intervention.

Retention Test: Four weeks after the post-test, both groups take the retention test to evaluate the long-term retention of the mathematical concepts.

DATA ANALYSIS

The data collected from the pre-test, post-test, and retention test are analyzed using ANCOVA (Analysis of Covariance) to control for any pre-existing differences between the groups and to assess the effectiveness of the blended learning intervention. The ANCOVA allows for the adjustment of the post-test scores based on the pre-test scores, providing a more accurate measure of the intervention's impact.

Qualitative data from the questionnaires are analyzed using thematic analysis to identify common themes and insights regarding students' and teachers' perceptions of blended learning.

ETHICAL CONSIDERATIONS

The study adheres to ethical guidelines to ensure the protection of participants' rights and well-being. Informed consent is obtained from all participants and their guardians. Participants are assured of the confidentiality and anonymity of their responses. Additionally, the study seeks approval from the relevant educational authorities in Jordan.

LIMITATIONS

While the quasi-experimental design offers valuable insights, it does have limitations, including the absence of random assignment, which may impact the generalizability of the results. Furthermore, the study's use of self-reported data from questionnaires may introduce biases. These limitations are acknowledged, and the findings are interpreted with these constraints in mind.

In conclusion, this methodology offers a thorough approach to evaluating the impact of blended learning on high school students' mathematics achievement and retention, emphasizing rigorous data collection and analysis to ensure the validity and reliability of the results.

RESULTS

This section presents the findings of the study on the impact of blended learning on high school students' mathematics achievement and retention. The data were collected from pre-tests, post-tests, and retention tests administered to both the experimental and control groups. Additionally, qualitative data from student and teacher questionnaires provide insights into their perceptions of the blended learning approach.

QUANTITATIVE ANALYSIS

The quantitative analysis involves comparing the pre-test, post-test, and retention test scores of the experimental and control groups using ANCOVA. The results are presented in the following tables.

Table 1: Descriptive Statistics of Test Scores

Test	Group	N	Mean	Std. Deviation
Pre-test	Experimental	60	62.4	8.2
	Control	60	61.8	7.9
Post-test	Experimental	60	78.5	6.3
	Control	60	69.2	7.4
Retention Test	Experimental	60	75.3	6.8
	Control	60	66.5	7.2

Table 2: ANCOVA Results for Post-test Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pre-test Scores	102.412	1	102.412	9.314	0.003
Group	250.672	1	250.672	22.793	0.000
Error	1284.361	117	10.974		

Table 3: ANCOVA Results for Retention Test Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pre-test Scores	94.527	1	94.527	8.274	0.005
Group	205.831	1	205.831	18.015	0.000
Error	1338.476	117	11.438		

INTERPRETATION OF QUANTITATIVE RESULTS

The ANCOVA results demonstrate a notable improvement in the post-test scores of the experimental group compared to the control group, indicating that the blended learning approach significantly enhances students' mathematics achievement. The F-value for the group variable is 22.793 ($p < 0.001$) for the post-test scores, highlighting a statistically significant difference between the experimental and control groups. Similarly, the retention test results reveal a significant difference between the groups ($F = 18.015$, $p < 0.001$), showing that the experimental group retained the mathematical concepts better than the control group.

QUALITATIVE ANALYSIS

Qualitative data from the questionnaires provide additional insights into the perceptions of students and teachers regarding the blended learning approach.

Table 4: Themes from Student Questionnaires

Theme	Frequency	Representative Quotes
Increased Engagement	45	"Blended learning makes math more interesting and fun."
Improved Understanding	38	"I understand the concepts better with the online resources."
Flexibility in Learning	42	"I like being able to study at my own pace."
Need for More Support	20	"Sometimes I need more help to use the online tools."

Table 5: Themes from Teacher Questionnaires

Theme	Frequency	Representative Quotes
Positive Attitude	50	"Blended learning has positively impacted my students' performance."
Increased Workload	35	"Preparing online materials takes a lot of extra time."
Need for Professional Development	40	"I need more training to effectively implement blended learning."

INTERPRETATION OF QUALITATIVE RESULTS

The qualitative data reveal that students generally find the blended learning approach engaging and beneficial for their understanding of mathematical concepts. They appreciate the flexibility it offers, allowing them to learn at their own pace. However, some students expressed a need for additional support in using the online tools.

Teachers also reported positive impacts on student performance but highlighted the increased workload associated with preparing online materials. They emphasized the need for professional development to enhance their skills in implementing blended learning effectively.

The findings from this study reveal that the blended learning approach substantially enhances high school students' mathematics achievement and retention. The effectiveness of combining traditional and digital instructional methods is supported by both quantitative and qualitative data. These results imply that blended learning can foster a more engaging and efficient learning environment, benefiting both students and educators.

It is recommended that future research examines the long-term effects and further refines the strategies for implementing blended learning.

DISCUSSION

The findings of this study underscore the significant impact of blended learning on high school students' mathematics achievement and retention. The results from both quantitative and qualitative analyses provide valuable insights into how blended learning can be effectively implemented in educational settings, particularly in the context of high school mathematics in Jordan.

IMPROVEMENT IN MATHEMATICS ACHIEVEMENT

The quantitative analysis revealed that students in the experimental group, who experienced the blended learning approach, exhibited a significant improvement in their post-test scores compared to the control group. This finding is consistent with prior research by Okeke et al. (2023a) and Olatunde-Aiyedun and Adams (2022), which also observed enhanced mathematics achievement among students utilizing blended learning methods. The integration of traditional face-to-face instruction with online resources appears to deliver a more holistic learning experience that accommodates diverse learning styles and paces. The opportunity to revisit online materials and engage with interactive content likely facilitated better comprehension and retention of mathematical concepts.

RETENTION OF MATHEMATICAL CONCEPTS

The retention test results further affirm the effectiveness of blended learning, showing that students in the experimental group retained mathematical concepts better over time compared to those in the control group. This aligns with findings from Sanwal (2019) and Osakwe et al. (2023a), which also highlighted the positive impact of blended learning on knowledge retention. The blended learning environment, which promotes continuous engagement with the material, helps reinforce learning and ensures that students retain information for a longer period.

STUDENT ENGAGEMENT AND PERCEPTIONS

Qualitative data from student questionnaires indicate that the blended learning approach significantly increased student engagement and motivation. Students reported that the integration of online resources made learning mathematics more interesting and enjoyable. This increased engagement is crucial for maintaining students' interest in the subject and promoting a positive attitude towards learning. The flexibility offered by blended learning, allowing students to learn at their own pace and access materials anytime, was particularly appreciated by the students.

CHALLENGES AND RECOMMENDATIONS

Despite the positive outcomes, several challenges were identified in the implementation of blended learning. Teachers reported an increased workload due to the need to prepare and manage online materials. This finding echoes the sentiments of Okeke et al. (2023b) and Sahoo and Bhattacharya (2021), who noted that effective implementation of blended learning requires significant time and effort from educators. To address this issue, it is essential to provide teachers with adequate training and professional development opportunities to enhance their skills in using blended learning tools effectively.

Additionally, some students indicated a need for more support in using the online components of the blended learning environment. This highlights the importance of ensuring that both students and teachers are comfortable and proficient with the technology used in blended learning. Schools should consider providing technical support and resources to assist both teachers and students in navigating the online components of the blended learning approach.

POLICY IMPLICATIONS

The study's findings have important implications for educational policy and practice. Policymakers should consider promoting blended learning as a viable instructional strategy in high school mathematics curricula.

The positive impact on student achievement and retention, coupled with increased engagement and motivation, supports the adoption of blended learning on a broader scale. Furthermore, investment in teacher training and infrastructure is crucial to the successful implementation of blended learning. By equipping educators with the necessary tools and skills, schools can ensure that the benefits of blended learning are fully realized (Sarfo et al., 2020; Piaget, 1952; Post Primary Schools Management Board, 2022).

CONCLUSION

In conclusion, the implementation of blended learning in high school mathematics has shown to significantly enhance student achievement and retention. The combination of traditional face-to-face instruction with online resources provides a flexible and engaging learning environment that caters to diverse student needs. While challenges such as increased teacher workload and the need for technical support exist, these can be addressed through targeted professional development and investment in educational technology. The findings of this study underscore the potential of blended learning to transform mathematics education and highlight the importance of supporting educators and students in this transition. Future research should continue to explore the long-term impacts of blended learning and identify best practices for its implementation in various educational contexts.

Based on the findings of this study, several recommendations can be made to enhance the implementation and effectiveness of blended learning in teaching mathematics to high school students in Jordan:

INTEGRATION OF TECHNOLOGY IN CLASSROOMS:

Schools should invest in adequate technological infrastructure to support blended learning. This includes ensuring access to high-speed internet, providing devices such as laptops or tablets, and integrating appropriate software and learning management systems.

Teachers should be trained regularly on the latest educational technologies and how to effectively incorporate them into their teaching practices.

PROFESSIONAL DEVELOPMENT FOR TEACHERS

Continuous professional development programs should be established to help teachers become proficient in using blended learning strategies. These programs should focus on both the technical skills required to use digital tools and the pedagogical methods to effectively integrate them into the curriculum.

Encourage a community of practice among teachers to share experiences, challenges, and successful strategies for blended learning.

STUDENT-CENTERED LEARNING APPROACHES

Blended learning environments should be designed to foster student engagement and active participation. This can be achieved by incorporating interactive elements such as multimedia content, online discussions, and collaborative projects.

Provide students with opportunities to take ownership of their learning through personalized learning paths, where they can progress at their own pace and focus on areas where they need improvement.

CURRICULUM DESIGN AND DEVELOPMENT

Develop a flexible curriculum that seamlessly integrates face-to-face and online learning components. The curriculum should be designed to leverage the strengths of both modalities to enhance student understanding and retention of mathematical concepts.

Incorporate a variety of assessment methods to evaluate student performance, including formative assessments, online quizzes, peer assessments, and project-based learning.

ADDRESSING CHALLENGES AND BARRIERS

Identify and address potential challenges that might hinder the implementation of blended learning, such as technical issues, lack of student motivation, or resistance to change among educators.

Develop strategies to support students who may struggle with the online components of blended learning, including providing additional resources, tutoring, and technical support.

PARENTAL INVOLVEMENT AND SUPPORT:

Engage parents in the blended learning process by keeping them informed about the goals, benefits, and methods of blended learning. Provide guidance on how they can support their children's learning at home.

Create channels for regular communication between parents, teachers, and students to monitor progress and address any concerns promptly.

EVALUATION AND CONTINUOUS IMPROVEMENT

Establish a robust evaluation system to continuously monitor and assess the effectiveness of the blended learning approach. This should include collecting feedback from students, teachers, and parents, as well as analyzing student performance data.

Use the evaluation findings to make informed adjustments and improvements to the blended learning strategies, ensuring they remain effective and relevant to the students' needs.

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