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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Abstract

The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in mathematics learning. A survey was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics learning. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves students' knowledge and skills, which in turn has a positive impact on their learning satisfaction. This study provides important implications for curriculum development in higher education to optimize the implementation of Blended Learning to improve the quality of mathematics learning.

Kata kunci

Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

Introduction

Currently, the rapid development of information and communication technology has changed the way of working in various institutions. One sector that has experienced a major transformation is in educational institutions, especially in higher education (Hashim et al., 2022). According to data from Databoks, in 2022 the use of technology in higher education institutions worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of a learning system that can occur anytime and anywhere. In higher education, the adoption of technology has become an inseparable part of the learning process. Students no longer rely on physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive learning experience.

One of the triggers for the increase in online learning is the Covid-19 Pandemic. This pandemic has caused all education sectors to close their institutions and have been forced to conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even though the Covid-19 pandemic has subsided, in fact the use of online learning systems in universities is still very much attached to both lecturers and students. Students often ask to do online learning again because it is considered to save more time and increase personal focus (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that combines face-to-face learning with online learning or commonly called blended learning (Gayatri et al., 2022).

Blended learning as a form of learning system by combining face-to-face learning with online or distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can be

adjusted to the needs of students because they are able to manage their time and study space more effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said, one of the obstacles in the blended learning system is in mathematics learning. Mathematics learning is considered to have a higher level of difficulty, so the use of the blended learning system is still in doubt. This is because students often find it difficult to follow mathematics material delivered digitally (Hoyles, 2018). Blended learning will work well if universities are able to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a curriculum appropriately to integrate mathematics learning into the blended learning system in their academics, it will create student learning satisfaction including improving their skills both in academic and non-academic environments (Abuhassna et al., 2020).

On the other hand, Rasheed et al. (2020) said, although the blended learning system offers various advantages, the success of this system is highly dependent on the knowledge they have. The knowledge possessed by students will allow them to integrate the mathematics learning system with the Blended learning method in their academic environment (Rasheed et al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics learning system, especially in the blended learning method. Students who lack good technological skills will allow them to face obstacles in accessing and reducing their overall satisfaction with the mathematics learning process (Cihad, 2021).

In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et al. (2019), Bervell & Umar (2020), Previtali & Scarozza (2019) who studied the effect of blended learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results showed that blended learning significantly influenced the learning satisfaction of students in Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended learning is still limited to character, attitude, environment, social factors, and also usage intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti & Sulistiyawati, 2020). Moreover, Hoyles (2018) stated that the use of the blended learning method in mathematics learning is still in doubt. Therefore, the current researcher intends to further develop blended learning research by adopting student satisfaction factors in the mathematics learning system in Indonesia considering that there are still very few researchers who study these factors, especially in 2024.

Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where the success of using the blended learning method in the student environment depends on the knowledge and expertise they have. Therefore, the researcher also adopts knowledge and expertise as mediating factors to find out whether the existence of knowledge and attitudes will change the satisfaction of learning mathematics of students in Indonesia in adopting the blended learning method or not. This research is expected to be a reference for institutions in understanding the factors that influence student satisfaction in learning mathematics using blended learning in order to be able to adjust learning methods that are more appropriate to student needs, as well as encourage a more active academic environment in adopting technology in the teaching and learning process, especially in mathematics.

Literature Review

Blended Learning

According to Zagouras et al. (2022) blended learning is an educational system that combines face-to-face learning with independent online learning that involves the use of digital technology. This system is able to offer convenience in terms of time, place, and learning methods that allow someone to access materials more flexibly (Li et al., 2022). especially for students who are considered to have the highest level of busyness compared to other students, both activities in the academic environment and outside academic activities (Suzianti & Paramadini, 2021). Alkhatib (2018) stated that with the blended learning system, students not only get direct learning instructions through lecturers in class, but are also able to utilize digital resources such as videos, interactive modules, and online discussion forums including in mathematics learning. Students who are familiar with technology and independent learning will tend to be more satisfied because they are able to control their own learning pace (Li et al., 2022). This system also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020). With the right support from institutions and a good curriculum, the implementation of blended learning can improve the quality of experience and provide higher satisfaction for students (Sarkar et al., 2021).

As previously mentioned, blended learning can have an impact on student learning satisfaction. Students who are familiar with technology and independent learning tend to feel more satisfied because they can control their learning pace (Rasheed et al., 2020). On the other hand, students' knowledge of basic concepts greatly determines how effectively they can use blended learning (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of the material being studied will be better able to access, understand, and apply information available online or face-to-face. This knowledge refers to students' expertise in using technology to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the ability to manage technological devices, and communication skills are very Students who have good technological skills will be more adaptable to the learning system. So that this is able to overcome challenges that may arise in the implementation of blended learning to significantly increase student learning satisfaction (Anthonysamy et al., 2020).

Blended Learning and Knowledge

According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts, skills, and understanding acquired by individuals through experience and education. In general, knowledge can be divided into two, namely declarative knowledge, knowledge of facts and concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al., 2022). In education, knowledge is the main foundation for effective learning, including in mathematics courses. Blended learning that combines face-to-face learning methods with online learning has great potential to influence and enrich students' mathematical knowledge (Li et al., 2019). This model provides wider access to various digital information sources such as learning videos and discussion forums that support the enrichment of students' declarative knowledge (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their time and place of study according to their needs, and gives them the opportunity to explore the material independently (Li et al., 2022). Through learning that is accessed online, students not only learn mathematics from core concepts but are also involved in practical applications that strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. They stated

that blended learning can make it easier for nursing students to gain knowledge and complete learning tasks better. In line with the research of Kang & Kim (2021) which found that blended learning can improve the knowledge of students in Korea in public health courses. This is because students can access materials more easily and repeat difficult parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the existence of a blended learning system can influence the increase in knowledge in students. Because blended learning can minimize students from fatigue and increase their focus. Based on the findings above, the researcher hopes that:

H1: Blended Learning has a positive effect on student knowledge in mathematics learning in Indonesia.

Blended Learning and Skill

Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through learning and experience (Schallock et al., 2018). In the world of education, student skills include critical thinking skills, problem-solving, communication, and technical skills in the blended learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning is able to provide students with opportunities to apply their knowledge in learning mathematics through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of technology in the learning process also facilitates cross-geographic collaboration through online platforms. This encourages communication and teamwork skills in a broader context. Thus, blended learning not only provides flexibility but also creates a rich environment for developing students' skills in learning more essential mathematics.

In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system was able to influence students' English language skills. They said that the blended learning system was able to provide a higher increase in students' English skills. In line with the research of Li et al. (2019) which found that blended learning can significantly improve the skills of nursing students. This is because blended learning is able to provide students with the flexibility to access materials according to their speed and learning style. Research by McCutcheon et al. (2018) also confirmed that blended learning was able to significantly influence skills in clinical supervisor learning. They argue that the blended learning method has a higher score because it has a higher level of efficiency. Based on the findings above, researchers hope that:

H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

Knowledge and Skill

Knowledge as a key element in students' mathematics learning process is the foundation for the development of more complex skills (Kim et al., 2019). In an academic environment, knowledge influences the way they solve problems, make decisions, and develop skills to a professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to shape skills. Good knowledge allows students to understand mathematical concepts in depth and apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in modern education, the skills expected of students go beyond cognitive knowledge which are

1 expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes
2 in mathematics learning (Coyne et al., 2018).

3 In addition, knowledge allows students to access various perspectives that enrich critical
4 and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource
5 that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-
6 Zamorano et al. (2019) in his research also stated that knowledge can significantly influence
7 students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which
8 states that there is a significant influence of knowledge on students' skills in listening and reading
9 comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens,
10 Students' knowledge in terms of capacity has been shown to have an effect on improving oral
11 presentation skills. Based on the findings above, the researcher hopes that:

12
13 H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

14 ***Knowledge and Learning Satisfaction***

15 Knowledge as the main foundation that influences how students understand the material, especially
16 in studying mathematics and applying it to various situations (Varadarajan, 2020). In studying
17 mathematics, this knowledge does not only include facts and theories, but also the abilities needed
18 to analyze information critically (Anderson et al., 2017). The more someone feels critical in
19 knowing something, the more their satisfaction in studying mathematics will increase (Z. Sun et
20 al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by students
21 towards their experience in studying mathematics, including students (Wong & Chapman, 2023).
22 Learning satisfaction lies in how the knowledge they gain affects the overall learning experience
23 (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of mathematics will be
24 better able to accept the material being studied so that they feel more satisfied. Conversely, lack
25 of knowledge will cause confusion, frustration, and decreased motivation which ultimately reduces
26 their level of satisfaction in studying mathematics (Haghighat et al., 2023). Therefore, knowledge
27 is a critical factor in creating a mathematics learning experience, especially for students to support
28 more optimal academic achievement.

29 Previous studies have found that knowledge can influence learning satisfaction. Such as research
30 conducted by Haghighat et al (2023) which found that knowledge can influence learning
31 satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who
32 found that knowledge can significantly influence student learning satisfaction in using flipped
33 classrooms. This is because academically students are required to study the material before face-
34 to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016)
35 it was also emphasized that the quality of knowledge can influence learning satisfaction in
36 undergraduate and postgraduate students. Quality knowledge allows students to be more effective
37 in achieving their academic goals. With these findings, the researcher hopes that:

38 H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in
39 Indonesia.

40 ***Skill and Learning Satisfaction***

Skills are a person's abilities based on learning and experience that enable them to perform certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the skills possessed are the basis for how effectively students can absorb the material and apply it in real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel more confident which allows them to understand mathematics material in depth and bring out their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al. (2019), which states that students' expertise in using flipped classrooms can significantly affect student learning satisfaction. This is because students who have independent learning and time management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom system. They consider flipped classrooms to have better efficiency in terms of time and place, so they can adjust their learning style. Based on previous findings, the researcher hopes that:

H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

Blended Learning and Knowledge and Learning Satisfaction

Blended learning as a learning method that combines face-to-face instruction with online learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al., 2021). In supporting the mathematics learning process, the blended learning method allows them to access information independently and flexibly, thereby increasing their knowledge in depth. Wider blended learning access to materials also facilitates their mathematical exploration of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual understanding in applying the blended learning method and increase students' confidence in mastering mathematics material. When students feel that they have good mathematical knowledge in the application of blended learning, it will increase their learning satisfaction and study it continuously (Murillo-Zamorano et al., 2019).

As in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve the knowledge of students in Korea in public health courses. Where blended learning is able to provide easier access to materials for students to repeat learning outside of class time. Kang & Kim (2021) also mentioned in their research that blended learning also affects the learning satisfaction of students in Korea in public health courses. On the other hand, research by Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can significantly affect student learning satisfaction in using flipped classrooms. The research of Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes that:

H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia mediated by Knowledge..

Blended Learning and Skill and Learning Satisfaction

The development of expertise and technological skills is an aspect that is often encouraged through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are trained to manage assignments and deadlines independently, thereby improving self-management skills,

especially in mathematics learning which is considered to have a higher level of difficulty (Ndlovu & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which states that blended learning can influence students' English language skills. In line with the research of McCutcheon et al. (2018) which states that blended learning can significantly influence skills in clinical supervisor learning. They said that learning through the blended learning method has a higher score because it has a better level of efficiency.

Research by Fisher et al. (2021) found that blended learning can influence student learning satisfaction at universities in Australia. With the blended learning method, students have the ability to access materials at any time and make it easier for them to adjust the learning process to their personal needs. On the other hand, expertise plays a very important role in supporting learning satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that students' skills in using flipped classrooms can significantly influence students' learning satisfaction. Lopes & Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia mediated by Skill.

Blended Learning and Knowledge and Skill

Blended learning that combines face-to-face instruction with online learning elements allows flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In the process of learning mathematics, blended learning provides an opportunity for students to learn basic concepts independently through digital resources, and use face-to-face sessions to deepen their understanding of more complex ones (Martínez et al., 2020). The knowledge gained through independent learning not only helps students understand the theory, but also builds analytical and problem-solving skills that are essential in their mathematics learning. Such as research conducted by Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. Kang & Kim (2021) also mentioned that blended learning can provide easier access to materials for students to repeat learning in difficult parts outside of class time to deepen their understanding.

Research by Li et al. (2019) stated that blended learning can influence students' skills in studying nursing education. This is because the flexibility provided by blended learning allows them to learn according to their rhythm and needs, as well as direct supervision from lecturers face to face to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al. (2019) found that knowledge can significantly influence students' skills in using flipped classrooms. The findings of Alfiani et al. (2024) also clarify that knowledge can influence students' listening and reading skills. Based on the findings above, researchers hope that:

H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through the mediation of Knowledge.

Knowledge and Skill and Learning Satisfaction

Knowledge is the main foundation in the learning process, especially in complex disciplines such as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand the theory but also to utilize their skills in solving more challenging mathematical problems (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will

1 contribute to students' level of learning satisfaction. Students with good knowledge tend to develop
2 more effective skills, which directly improve their learning process (Kim et al., 2019). So that the
3 existence of knowledge and skills will facilitate students' mathematics learning that is more
4 meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

5
6 Like the research conducted by Alfiani et al. (2024) which states that there is a significant influence
7 of knowledge on students' skills in listening and reading comprehension. In line with the findings
8 of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of capacity has
9 been shown to have an effect on improving oral presentation skills. When students have good
10 knowledge, they tend to be more confident in conveying information and are able to communicate
11 their ideas in a structured manner. Haghighat et al (2023) also found that knowledge can influence
12 learning satisfaction in nursing students. Knowledge is a critical factor in creating a mathematics
13 learning experience, especially for students to support more optimal academic achievement. On
14 the other hand, Murillo-Zamorano et al. (2019) explained that students' expertise in using flipped
15 classrooms can significantly influence students' learning satisfaction. This is because students who
16 are skilled in utilizing the flipped classroom method tend to be more prepared to face face-to-face
17 sessions, because they have a basic understanding through independent learning. Lopes & Soares
18 (2018) also strengthens, where skills can increase learning satisfaction higher in the flipped
19 classroom system. Based on the findings above, the researcher hopes that:

20 H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through
21 Skill mediation.

22 **Research Methodology**

23 Data collection in this study was conducted using quantitative survey techniques. This survey was
24 distributed to university students in Indonesia who had been involved in Blended Learning-based
25 mathematics learning. Respondents were selected using the snowball sampling method, where
26 initial respondents were recruited based on social networks, who then recommended other relevant
27 respondents. This technique was used because it is difficult to reach a wider population directly.
28 On the other hand, the success and efficiency of the snowball sampling approach depend almost
29 entirely on the personal or professional contacts of the researcher (Rahman, 2023). The
30 questionnaire used consisted of several parts, including questions about the demographics of
31 respondents (such as age, gender, and education level) as well as questions related to their
32 experiences in using the Blended Learning method for mathematics learning. This survey was
33 conducted online to ensure wider reach and ease of access for respondents. The number of samples
34 collected and eligible for analysis in this study was 304 students based on gender, education level,
35 gadgets used in learning on several islands in Indonesia (See Table 1).

36
37 The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning
38 Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 =
39 strongly agree) to assess respondents' perceptions of the various aspects studied. The following is
40 a description of each variable:

- 41 1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using
42 Blended Learning in learning, time flexibility, ease of access to materials, and integration of

online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).

2. Knowledge (KN): Measures how well students understand mathematical concepts through Blended Learning. Questions include assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

3. Skill (SK): Measures students' skills in solving mathematical problems and using tools provided through the Blended Learning platform. Related items include analytical skills, problem solving, and application of knowledge in practical situations. SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71
	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91

	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Uji Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740			
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735			
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			

Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Uji Structural Model

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R²), and Effect size (f²). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5. Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students to repeat difficult material, which ultimately improves their understanding of complex mathematical concepts. In addition, Blended Learning allows students to learn at their own pace, which is very important in learning mathematics, because this subject often requires extra time to understand abstract concepts and requires repetition of material. With wider access to digital resources, such as learning videos and interactive modules, students can explore various ways to understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states that the Blended Learning method is able to increase student engagement and motivation to study challenging topics, such as mathematics, because this method provides flexibility in learning styles. This is consistent with research findings showing that knowledge gained through Blended Learning includes not only theoretical understanding but also the ability to apply these concepts in a broader context.

The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the

1 importance of skills in technology-based learning, where Blended Learning allows students to
2 hone the technical and analytical skills needed to solve mathematical problems. The use of
3 technology in the learning process, such as online discussion forums and computer-based practice
4 questions, provides opportunities for students to practice and apply mathematical knowledge in
5 real situations. This finding is in line with research by McCutcheon et al. (2018), which shows that
6 Blended Learning provides a significant increase in students' skills, because this method allows
7 them to learn independently and apply relevant skills in various situations. In the context of
8 mathematics learning, students are faced with the challenge of understanding and solving complex
9 problems. The use of Blended Learning helps them practice problem-solving skills more
10 effectively, because students can access the material at any time and repeat the exercises as needed.

11 Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive
12 relationship, indicating that students who gain greater knowledge feel more satisfied with their
13 learning experience. Thus accepting H3. The knowledge gained during the learning process has a
14 significant direct effect on learning satisfaction. This indicates that students who feel they have
15 gained adequate knowledge tend to be more satisfied with their learning experience. This finding
16 is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased
17 knowledge during the learning process contributes to higher learning satisfaction, especially when
18 students feel that they can apply the knowledge they have gained in practical contexts. In
19 mathematics learning, learning satisfaction is often related to how well students understand the
20 concepts taught and their ability to solve the problems faced. When students feel that they gain a
21 deep understanding of mathematics topics through Blended Learning, their satisfaction with the
22 learning process increases, because they feel more prepared and confident in facing academic
23 challenges.

24 Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect,
25 indicating that higher knowledge significantly improves students' skills. It can be concluded to
26 accept H4. This finding is in line with the concept that good knowledge is the foundation for
27 developing higher skills, especially in complex subjects such as mathematics. In mathematics
28 learning, in-depth knowledge of theoretical concepts provides a strong foundation for students to
29 apply this understanding in practical contexts, such as problem solving and analysis. According to
30 Li et al. (2019), the knowledge gained through Blended Learning allows students to improve their
31 problem-solving skills because they can access various digital resources that help them understand
32 concepts more deeply. With a strong understanding of theory, students are better prepared to apply
33 their knowledge in real situations, so their critical and analytical thinking skills also improve.

34 Knowledge not only helps students understand the subject matter but also shapes their
35 ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that
36 declarative knowledge (knowledge of facts and concepts) is often the basis for the development of
37 procedural skills (how to do something), which are important in mathematics learning. Students
38 who have strong declarative knowledge will be better able to develop procedural skills, such as
39 the ability to solve equations or solve complex mathematical problems. Burger et al. (2019) also
40 showed that in-depth knowledge facilitates the development of more sophisticated skills, such as
41 critical thinking and problem-solving skills. In the context of Blended Learning, students can
42 utilize various materials available online to strengthen their knowledge and then apply that
43 knowledge in practice questions or discussions that require high-level problem-solving skills.

Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive effect, meaning that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated that students who have better skills in using learning technology tend to be more satisfied with their learning process, especially because they feel more capable of solving problems and managing independent learning. In the context of mathematics learning, skills developed through Blended Learning, such as analytical and problem-solving skills, provide students with greater self-confidence, which ultimately increases their satisfaction.

Students who feel they have developed skills relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they are able to see practical applications of the knowledge they have acquired. This finding is also supported by research by Rajabalee & Santally (2021), which states that skills developed through technology-based learning significantly increase student satisfaction, because they feel more prepared to face challenges in the real world.

The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta = 0.145$, T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the important role of skills in bridging the relationship between Blended Learning and student learning satisfaction, especially in mathematics learning. Blended Learning, with an approach that combines online and face-to-face learning, provides students with the opportunity to develop better problem-solving skills. In the context of mathematics learning, these skills are very important because students are often faced with questions that require in-depth analysis and application of theory to real situations. Blended Learning, with the provision of online materials such as interactive exercises and simulations, provides space for students to practice and deepen their understanding independently.

The skills acquired through the Blended Learning method then have a positive impact on student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in using learning technology and are able to solve academic problems more effectively tend to be more satisfied with their learning experience. This also applies to mathematics learning, where students who feel more skilled in solving math problems tend to feel more confident and satisfied with the learning process. In addition, the skills developed through Blended Learning not only include technical skills in using math tools, but also include critical thinking and logical skills, which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended Learning encourages students to think independently and apply critical thinking skills in practical situations. This is very relevant in the context of mathematics learning, where students are often faced with complex problems that require a systematic and logic-based approach.

Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$, T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the relationship between Blended Learning and Skills. As highlighted in the study by Burger et al. (2019), good theoretical knowledge often forms a solid foundation for the development of practical skills. In the context of mathematics learning, students who have a deep understanding of mathematical theories tend to be better able to apply this knowledge in solving real problems, which improves their skills. Blended Learning provides students with the opportunity to learn

1 mathematical theories in various formats (text, video, interactive exercises), allowing them to learn
2 in a way that best suits their learning style. The knowledge gained from this method then allows
3 students to develop better skills in solving mathematical problems, both in the classroom and in
4 real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning
5 contributed significantly to the development of practical skills in areas requiring deep conceptual
6 understanding, including mathematics.

7 The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-
8 stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning
9 indirectly contributes to learning satisfaction through skill development. As found in this study,
10 better skills provide students with higher self-confidence, which in turn increases their satisfaction
11 with the learning experience. Rajabalee & Santally (2021) showed that students who feel skilled
12 in using learning technology and applying mathematical concepts tend to be more satisfied with
13 their learning process. In mathematics learning, skills developed through Blended Learning, such
14 as the ability to solve problems or use mathematical technology (e.g., graphing calculators,
15 modeling software), play an important role in increasing students' self-confidence. The more
16 skilled students are in utilizing these tools, the more satisfied they are with their learning outcomes.
17 This indirect effect shows that Blended Learning not only provides direct benefits in improving
18 skills but also helps increase students' learning satisfaction through the development of these skills.

19 The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta =$
20 0.214, T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction.
21 It is concluded that H9 is accepted. Students who have a deep understanding of mathematical
22 concepts are more likely to be able to apply their knowledge in practical situations, leading to
23 better skill development. Demir et al. (2022) found that declarative knowledge (theoretical
24 knowledge) often acts as an important foundation for the development of procedural skills
25 (practical application). In mathematics learning, strong theoretical knowledge helps students
26 develop better analytical and problem-solving skills, which ultimately increases their learning
27 satisfaction. In the context of Blended Learning, the knowledge gained through various online
28 resources allows students to practice and strengthen their skills in solving mathematical problems.
29 These skills not only help students achieve better academic results but also increase their
30 satisfaction with the learning process, as they feel more prepared and able to overcome academic
31 challenges.

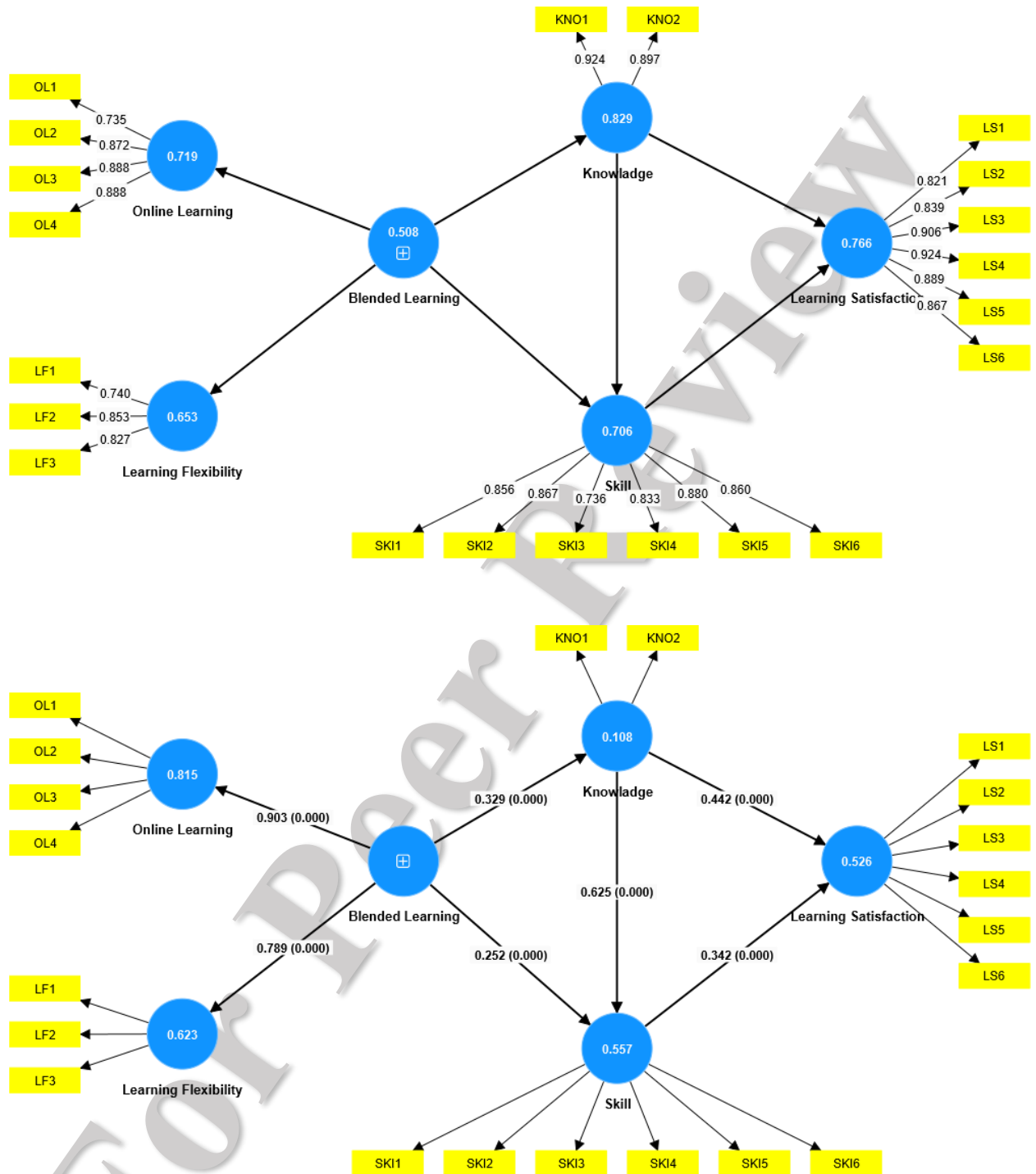


Figure 1. Outer and Inner Model

The coefficient of determination (R^2) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R^2 values of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used in

SEM testing to measure exogenous constructs in explaining endogenous constructs by recalculating R² by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large, indicating that knowledge greatly contributes to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing the importance of knowledge acquisition in shaping positive learning outcomes.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Conclusion

This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in mathematics learning, by considering the role of Knowledge and Skill as mediators. This study aims to explore how Blended Learning can improve students' knowledge and skills, which ultimately affect their level of satisfaction in the learning process. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges.

These findings have important implications for educational institutions, especially in mathematics teaching. Blended Learning has proven effective in improving student learning outcomes, so the

application of this method needs to be expanded and deepened in the higher education curriculum. Institutions need to provide more interactive content, digital learning aids, and adequate technological support so that students can optimally utilize the Blended Learning method. In addition, training for lecturers to integrate Blended Learning more effectively is also needed so that the learning process becomes more dynamic and relevant to student needs. This study has several limitations that need to be considered. First, the sampling technique used, such as snowball sampling, can limit the generalizability of the findings because the resulting sample may not be fully representative of the wider student population. Second, this study used a cross-sectional design, which only captures the relationship between variables at one point in time. As a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction cannot be clearly identified.

For future research, it is recommended to use a longitudinal design to measure changes in student attitudes and behavior over time in the context of Blended Learning. In addition, further research can use more diverse and representative sampling techniques so that the results can be more generalized. Future research can also explore other variables such as self-regulation, technology acceptance, or learning engagement as factors that can influence the success of Blended Learning in increasing student learning satisfaction.

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36 y

Bukti Konfirmasi Review dan Hasil Review Pertama

tanggal 19 Mei 2025



Khoerul Umam <khoerul.umam@uhamka.ac.id>

251676324 (Cogent Education) A revise decision has been made on your submission2 pesan

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19-May-2025

Dear Dr Khoerul Umam:

Your manuscript, "The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities" submitted to Cogent Education, has now been considered.

We would like to see some substantial revisions made to your manuscript before publication. Therefore, I invite you to respond to our comments and revise your manuscript consistent with the advice provided by our reviewers.

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode or by using bold or coloured text.

To submit a revision, go to <https://rp.tandfonline.com/submission/flow?submissionId=251676324&step=1>. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

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Once again, thank you for submitting your manuscript to Cogent Education and I look forward to receiving your revision.

Sincerely,
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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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Manuscript ID	OAED-2025-2964
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Keywords	Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education
Classifications	Mathematics Education < Subject Specific Education < Education < Social Sciences, Science, Technology, Engineering & Mathematics (STEM) Education < Subject Specific Education < Education < Social Sciences, Educational Technology < Education < Social Sciences, Higher Education < Education < Social Sciences, Education - Social Sciences < Social Sciences < Social Sciences
Abstract	The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. **Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance

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1 The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in 2 Learning Mathematics in Indonesian Universities

3 Abstract

4 The rapid development of information and communication technology has affected the
5 education sector, especially in higher education. The blended learning method, which combines
6 face-to-face and online learning, is increasingly popular among students. This study aims to
7 analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in
8 mathematics learning. A survey was conducted on 304 students from various regions in Indonesia
9 who were involved in Blended Learning mathematics learning. The analysis was carried out using
10 the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study
11 indicate that Blended Learning significantly improves students' knowledge and skills, which in
12 turn has a positive impact on their learning satisfaction. This study provides important
13 implications for curriculum development in higher education to optimize the implementation of
14 Blended Learning to improve the quality of mathematics learning.

15 Kata kunci

16 Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

17

18 Introduction

19 Currently, the rapid development of information and communication technology has
20 changed the way of working in various institutions. One sector that has experienced a major
21 transformation is in educational institutions, especially in higher education (Hashim et al., 2022).
22 According to data from Databoks, in 2022 the use of technology in higher education institutions
23 worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of
24 a learning system that can occur anytime and anywhere. In higher education, the adoption of
25 technology has become an inseparable part of the learning process. Students no longer rely on
26 physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access
27 lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This
28 shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive
29 learning experience.

30 One of the triggers for the increase in online learning is the Covid-19 Pandemic. This
31 pandemic has caused all education sectors to close their institutions and have been forced to
32 conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery
33 that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions
34 to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even
35 though the Covid-19 pandemic has subsided, in fact the use of online learning systems in
36 universities is still very much attached to both lecturers and students. Students often ask to do
37 online learning again because it is considered to save more time and increase personal focus
38 (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that
39 combines face-to-face learning with online learning or commonly called blended learning
40 (Gayatri et al., 2022).

Commented [b n1]: You state that knowledge and skills improve, "which in turn has a positive impact" on satisfaction. Because your structural model relies heavily on mediation, you must use precise methodological terminology in the abstract. Explicitly state whether Perceived Knowledge and Skill served as "full" or "partial" mediators in this relationship.

Commented [b n2]: High-impact quantitative journals expect abstracts to report more than just the methodological name. While you mention using SEM-PLS, you must include key predictive parameters to prove empirical rigor upfront.

Commented [b n3]: Check your statistics carefully. The claim that "4.9 billion people" are in higher education institutions worldwide is factually incorrect (global higher education enrollment is roughly 250 million; 4.9 billion likely refers to total global internet users). Update this with accurate data specific to higher education.

Commented [b n4]: Avoid sentence fragments. The sentence starting with "Where they are able to access..." is grammatically incomplete. Combine it with the previous sentence or rephrase it entirely (e.g., "This allows students to access lecture materials...").

Commented [b n5]: Contextualize your citations. When citing Chen (2023) stating that students "often ask to do online learning," clarify whether this finding is based on an Indonesian context or a global one, as student preferences vary by region.

1 Blended learning as a form of learning system by combining face-to-face learning with online or
 2 distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can
 3 be adjusted to the needs of students because they are able to manage their time and study space
 4 more effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have
 5 implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said,
 6 one of the obstacles in the blended learning system is in mathematics learning. Mathematics
 7 learning is considered to have a higher level of difficulty, so the use of the blended learning
 8 system is still in doubt. This is because students often find it difficult to follow mathematics
 9 material delivered digitally (Hoyles, 2018). Blended learning will work well if universities are able
 10 to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a
 11 curriculum appropriately to integrate mathematics learning into the blended learning system in
 12 their academics, it will create student learning satisfaction including improving their skills both in
 13 academic and non-academic environments (Abuhassna et al., 2020).

Commented [b n6]: Fix the ambiguous pronoun reference. You write, "He said, this system allows..." immediately following a citation of Zagouras et al. (2022). It is unclear who "He" refers to. Use the authors' names or passive voice.

Commented [b n7]: Clarify the 80% statistic cited from Yulianti & Sulistiyawati (2020). Does this mean 80% of all Indonesian universities have implemented it, or that courses are delivered 80% online and 20% face-to-face? Precision is key.

14 On the other hand, Rasheed et al. (2020) said, although the blended learning system
 15 offers various advantages, the success of this system is highly dependent on the knowledge they
 16 have. The knowledge possessed by students will allow them to integrate the mathematics
 17 learning system with the Blended learning method in their academic environment (Rasheed et
 18 al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics
 19 learning system, especially in the blended learning method. Students who lack good
 20 technological skills will allow them to face obstacles in accessing and reducing their overall
 21 satisfaction with the mathematics learning process (Cihad, 2021).

Commented [b n8]: Define "knowledge" more precisely. Phrases like "the knowledge they have" are too broad for a research variable. Are you referring to digital literacy, technological pedagogical content knowledge (TPACK), or foundational mathematical knowledge?

22 In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et
 23 al. (2019), Bervell & Umar (2020), Previtali & Scarozza (2019) who studied the effect of blended
 24 learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results
 25 showed that blended learning significantly influenced the learning satisfaction of students in
 26 Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended
 27 learning is still limited to character, attitude, environment, social factors, and also usage
 28 intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti
 29 & Sulistiyawati, 2020). Moreover, Hoyles (2018) stated that the use of the blended learning
 30 method in mathematics learning is still in doubt. Therefore, the current researcher intends to
 31 further develop blended learning research by adopting student satisfaction factors in the
 32 mathematics learning system in Indonesia considering that there are still very few researchers
 33 who study these factors, especially in 2024.

Commented [b n9]: Explicitly link these variables to the Indonesian context. Before moving to the research gap in the next paragraph, briefly state if there is known data about the digital literacy levels of Indonesian university students.

Commented [b n10]: Categorize your geographic comparisons consistently. You list "Australia, Singapore, Europe, and Italy." Europe is a continent, while the others are countries (and Italy is inside Europe). Adjust this to specific countries or broader regions.

34 Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where
 35 the success of using the blended learning method in the student environment depends on the
 36 knowledge and expertise they have. Therefore, the researcher also adopts knowledge and
 37 expertise as mediating factors to find out whether the existence of knowledge and attitudes will
 38 change the satisfaction of learning mathematics of students in Indonesia in adopting the blended
 39 learning method or not. This research is expected to be a reference for institutions in
 40 understanding the factors that influence student satisfaction in learning mathematics using
 41 blended learning in order to be able to adjust learning methods that are more appropriate to
 42 student needs, as well as encourage a more active academic environment in adopting technology

Commented [b n11]: Formulate 2–3 explicit research questions. The introduction currently ends on a broad statement of expectation. It must conclude with clear, numbered, or bulleted research questions that the paper will answer.

1 in the teaching and learning process, especially in mathematics.

2 Literature Review

3 Blended Learning

4 According to Zagouras et al. (2022) blended learning is an educational system that combines face-
5 to-face learning with independent online learning that involves the use of digital technology. This
6 system is able to offer convenience in terms of time, place, and learning methods that allow
7 someone to access materials more flexibly (Li et al., 2022). especially for students who are
8 considered to have the highest level of busyness compared to other students, both activities in
9 the academic environment and outside academic activities (Suzianti & Paramadini, 2021).
10 Alkhatib (2018) stated that with the blended learning system, students not only get direct
11 learning instructions through lecturers in class, but are also able to utilize digital resources such
12 as videos, interactive modules, and online discussion forums including in mathematics learning.
13 Students who are familiar with technology and independent learning will tend to be more
14 satisfied because they are able to control their own learning pace (Li et al., 2022). This system
15 also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020).
16 With the right support from institutions and a good curriculum, the implementation of blended
17 learning can improve the quality of experience and provide higher satisfaction for students
18 (Sarkar et al., 2021).

19

20 As previously mentioned, blended learning can have an impact on student learning satisfaction.
21 Students who are familiar with technology and independent learning tend to feel more satisfied
22 because they can control their learning pace (Rasheed et al., 2020). On the other hand, students'
23 knowledge of basic concepts greatly determines how effectively they can use blended learning
24 (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of
25 the material being studied will be better able to access, understand, and apply information
26 available online or face-to-face. This knowledge refers to students' expertise in using technology
27 to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the
28 ability to manage technological devices, and communication skills are very Students who have
29 good technological skills will be more adaptable to the learning system. So that this is able to
30 overcome challenges that may arise in the implementation of blended learning to significantly
31 increase student learning satisfaction (Anthonysamy et al., 2020).

32 Blended Learning and Knowledge

33 According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts,
34 skills, and understanding acquired by individuals through experience and education. In general,
35 knowledge can be divided into two, namely declarative knowledge, knowledge of facts and
36 concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al.,
37 2022). In education, knowledge is the main foundation for effective learning, including in
38 mathematics courses. Blended learning that combines face-to-face learning methods with online
39 learning has great potential to influence and enrich students' mathematical knowledge (Li et al.,
40 2019). This model provides wider access to various digital information sources such as learning

Commented [b n12]: There are notable grammatical issues that disrupt the academic flow. For example, the sentence fragment starting with "especially for students..." needs to be connected to the previous sentence. Additionally, there is a typo in the second paragraph: "communication skills are very Students who have..." Please thoroughly proofread for syntax.

Commented [b n13]: When you mention students utilizing "digital resources such as videos, interactive modules," you must specify what this looks like in mathematics. Are you referring to dynamic geometry software (like GeoGebra), computer algebra systems, or simply recorded whiteboard lectures?

Commented [b n14]: You rely heavily on general education citations (e.g., Anthonysamy et al., 2020). For a high-impact journal, ensure that your foundational paragraph sets up the specific context of the study rather than relying solely on generic blended learning definitions.

Commented [b n15]: You use studies based on nursing students (Li et al., 2019) and public health students (Kang & Kim, 2021) to justify a hypothesis about mathematics. The epistemological nature of these fields is vastly different. You must find literature specific to STEM or quantitative fields.

1 videos and discussion forums that support the enrichment of students' declarative knowledge
 2 (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their
 3 time and place of study according to their needs, and gives them the opportunity to explore the
 4 material independently (Li et al., 2022). Through learning that is accessed online, students not
 5 only learn mathematics from core concepts but are also involved in practical applications that
 6 strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study
 7 of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing
 8 students. They stated that blended learning can make it easier for nursing students to gain
 9 knowledge and complete learning tasks better. In line with the research of Kang & Kim (2021)
 10 which found that blended learning can improve the knowledge of students in Korea in public
 11 health courses. This is because students can access materials more easily and repeat difficult
 12 parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the
 13 existence of a blended learning system can influence the increase in knowledge in students.
 14 Because blended learning can minimize students from fatigue and increase their focus. Based on
 15 the findings above, the researcher hopes that:

16

17 H1: Blended Learning has a positive effect on student knowledge in mathematics learning in
 18 Indonesia.

19 **Blended Learning and Skill**

20 Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and
 21 efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through
 22 learning and experience (Schallock et al., 2018). In the world of education, student skills include
 23 critical thinking skills, problem-solving, communication, and technical skills in the blended
 24 learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning
 25 is able to provide students with opportunities to apply their knowledge in learning mathematics
 26 through online problem-based activities or case studies, thereby strengthening their critical
 27 thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of
 28 technology in the learning process also facilitates cross-geographic collaboration through online
 29 platforms. This encourages communication and teamwork skills in a broader context. Thus,
 30 blended learning not only provides flexibility but also creates a rich environment for developing
 31 students' skills in learning more essential mathematics.

32 In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system
 33 was able to influence students' English language skills. They said that the blended learning system
 34 was able to provide a higher increase in students' English skills. In line with the research of Li et
 35 al. (2019) which found that blended learning can significantly improve the skills of nursing
 36 students. This is because blended learning is able to provide students with the flexibility to access
 37 materials according to their speed and learning style. Research by McCutcheon et al. (2018) also
 38 confirmed that blended learning was able to significantly influence skills in clinical supervisor
 39 learning. They argue that the blended learning method has a higher score because it has a higher
 40 level of efficiency. Based on the findings above, researchers hope that:

Commented [b n16]: Hypotheses should be theoretical and universal. Including "in Indonesia" in H1 makes it sound like a demographic survey rather than a test of a theoretical construct. Remove the geographic constraint from the hypothesis itself (apply this to all hypotheses).

Commented [b n17]: You define declarative and procedural knowledge, but you do not explicitly state which type of knowledge your study actually measures. The literature review must directly align with your survey instrument.

1 H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

2 **Knowledge and Skill**

3 Knowledge as a key element in students' mathematics learning process is the foundation
4 for the development of more complex skills (Kim et al., 2019). In an academic environment,
5 knowledge influences the way they solve problems, make decisions, and develop skills to a
6 professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to
7 shape skills. Good knowledge allows students to understand mathematical concepts in depth and
8 apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in
9 modern education, the skills expected of students go beyond cognitive knowledge which are
10 expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes
11 in mathematics learning (Coyne et al., 2018).

12 In addition, knowledge allows students to access various perspectives that enrich critical
13 and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource
14 that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-
15 Zamorano et al. (2019) in his research also stated that knowledge can significantly influence
16 students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which
17 states that there is a significant influence of knowledge on students' skills in listening and reading
18 comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens,
19 Students' knowledge in terms of capacity has been shown to have an effect on improving oral
20 presentation skills. Based on the findings above, the researcher hopes that:

21

22 H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

23 **Knowledge and Learning Satisfaction**

24 Knowledge as the main foundation that influences how students understand the material,
25 especially in studying mathematics and applying it to various situations (Varadarajan, 2020). In
26 studying mathematics, this knowledge does not only include facts and theories, but also the
27 abilities needed to analyze information critically (Anderson et al., 2017). The more someone feels
28 critical in knowing something, the more their satisfaction in studying mathematics will increase
29 (Z. Sun et al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by
30 students towards their experience in studying mathematics, including students (Wong &
31 Chapman, 2023). Learning satisfaction lies in how the knowledge they gain affects the overall
32 learning experience (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of
33 mathematics will be better able to accept the material being studied so that they feel more
34 satisfied. Conversely, lack of knowledge will cause confusion, frustration, and decreased
35 motivation which ultimately reduces their level of satisfaction in studying mathematics
36 (Haghighat et al., 2023). Therefore, knowledge is a critical factor in creating a mathematics
37 learning experience, especially for students to support more optimal academic achievement.

38 Previous studies have found that knowledge can influence learning satisfaction. Such as research
39 conducted by Haghighat et al (2023) which found that knowledge can influence learning

1 satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who
2 found that knowledge can significantly influence student learning satisfaction in using flipped
3 classrooms. This is because academically students are required to study the material before face-
4 to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016)
5 it was also emphasized that the quality of knowledge can influence learning satisfaction in
6 undergraduate and postgraduate students. Quality knowledge allows students to be more
7 effective in achieving their academic goals. With these findings, the researcher hopes that:

8 H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in
9 Indonesia.

10 ***Skill and Learning Satisfaction***

11 Skills are a person's abilities based on learning and experience that enable them to perform
12 certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the
13 skills possessed are the basis for how effectively students can absorb the material and apply it in
14 real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel
15 more confident which allows them to understand mathematics material in depth and bring out
16 their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al.
17 (2019), which states that students' expertise in using flipped classrooms can significantly affect
18 student learning satisfaction. This is because students who have independent learning and time
19 management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares
20 (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom
21 system. They consider flipped classrooms to have better efficiency in terms of time and place, so
22 they can adjust their learning style. Based on previous findings, the researcher hopes that:

23

24 H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

25 ***Blended Learning and Knowledge and Learning Satisfaction***

26 Blended learning as a learning method that combines face-to-face instruction with online
27 learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al.,
28 2021). In supporting the mathematics learning process, the blended learning method allows
29 them to access information independently and flexibly, thereby increasing their knowledge in
30 depth. Wider blended learning access to materials also facilitates their mathematical exploration
31 of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual
32 understanding in applying the blended learning method and increase students' confidence in
33 mastering mathematics material. When students feel that they have good mathematical
34 knowledge in the application of blended learning, it will increase their learning satisfaction and
35 study it continuously (Murillo-Zamorano et al., 2019).

36 As in the study of Li et al. (2019), where blended learning can effectively improve the
37 knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve
38 the knowledge of students in Korea in public health courses. Where blended learning is able to
39 provide easier access to materials for students to repeat learning outside of class time. Kang &

1 Kim (2021) also mentioned in their research that blended learning also affects the learning
2 satisfaction of students in Korea in public health courses. On the other hand, research by
3 Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students.
4 In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can
5 significantly affect student learning satisfaction in using flipped classrooms. The research of
6 Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student
7 learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes
8 that:

9 H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia
10 mediated by Knowledge..

11 ***Blended Learning and Skill and Learning Satisfaction***

12 The development of expertise and technological skills is an aspect that is often encouraged
13 through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are
14 trained to manage assignments and deadlines independently, thereby improving self-
15 management skills, especially in mathematics learning which is considered to have a higher level
16 of difficulty (Ndlovu & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which
17 states that blended learning can influence students' English language skills. In line with the
18 research of McCutcheon et al. (2018) which states that blended learning can significantly
19 influence skills in clinical supervisor learning. They said that learning through the blended
20 learning method has a higher score because it has a better level of efficiency.

21

22 Research by Fisher et al. (2021) found that blended learning can influence student learning
23 satisfaction at universities in Australia. With the blended learning method, students have the
24 ability to access materials at any time and make it easier for them to adjust the learning process
25 to their personal needs. On the other hand, expertise plays a very important role in supporting
26 learning satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that
27 students' skills in using flipped classrooms can significantly influence students' learning
28 satisfaction. Lopes & Soares (2018) also showed that skills can increase learning satisfaction
29 higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

30 H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia
31 mediated by Skill.

32 ***Blended Learning and Knowledge and Skill***

33 Blended learning that combines face-to-face instruction with online learning elements allows
34 flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In
35 the process of learning mathematics, blended learning provides an opportunity for students to
36 learn basic concepts independently through digital resources, and use face-to-face sessions to
37 deepen their understanding of more complex ones (Martínez et al., 2020). The knowledge gained
38 through independent learning not only helps students understand the theory, but also builds
39 analytical and problem-solving skills that are essential in their mathematics learning. Such as

1 research conducted by Li et al. (2019), where blended learning can effectively improve the
2 knowledge of nursing students. Kang & Kim (2021) also mentioned that blended learning can
3 provide easier access to materials for students to repeat learning in difficult parts outside of class
4 time to deepen their understanding.

5 Research by Li et al. (2019) stated that blended learning can influence students' skills in studying
6 nursing education. This is because the flexibility provided by blended learning allows them to
7 learn according to their rhythm and needs, as well as direct supervision from lecturers face to
8 face to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al.
9 (2019) found that knowledge can significantly influence students' skills in using flipped
10 classrooms. The findings of Alfiani et al. (2024) also clarify that knowledge can influence students'
11 listening and reading skills. Based on the findings above, researchers hope that:

12

13 H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through
14 the mediation of Knowledge.

15 ***Knowledge and Skill and Learning Satisfaction***

16 Knowledge is the main foundation in the learning process, especially in complex disciplines such
17 as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand
18 the theory but also to utilize their skills in solving more challenging mathematical problems
19 (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will
20 contribute to students' level of learning satisfaction. Students with good knowledge tend to
21 develop more effective skills, which directly improve their learning process (Kim et al., 2019). So
22 that the existence of knowledge and skills will facilitate students' mathematics learning that is
23 more meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

24

25 Like the research conducted by Alfiani et al. (2024) which states that there is a significant
26 influence of knowledge on students' skills in listening and reading comprehension. In line with
27 the findings of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of
28 capacity has been shown to have an effect on improving oral presentation skills. When students
29 have good knowledge, they tend to be more confident in conveying information and are able to
30 communicate their ideas in a structured manner. Haghighat et al (2023) also found that
31 knowledge can influence learning satisfaction in nursing students. Knowledge is a critical factor
32 in creating a mathematics learning experience, especially for students to support more optimal
33 academic achievement. On the other hand, Murillo-Zamorano et al. (2019) explained that
34 students' expertise in using flipped classrooms can significantly influence students' learning
35 satisfaction. This is because students who are skilled in utilizing the flipped classroom method
36 tend to be more prepared to face face-to-face sessions, because they have a basic understanding
37 through independent learning. Lopes & Soares (2018) also strengthens, where skills can increase
38 learning satisfaction higher in the flipped classroom system. Based on the findings above, the
39 researcher hopes that:

1 H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia
2 through Skill mediation.

3

4 Research Methodology

5 Data collection in this study was conducted using quantitative survey techniques. This survey was
6 distributed to university students in Indonesia who had been involved in Blended Learning-based
7 mathematics learning. Respondents were selected using the snowball sampling method, where
8 initial respondents were recruited based on social networks, who then recommended other
9 relevant respondents. This technique was used because it is difficult to reach a wider population
10 directly. On the other hand, the success and efficiency of the snowball sampling approach depend
11 almost entirely on the personal or professional contacts of the researcher (Rahman, 2023). The
12 questionnaire used consisted of several parts, including questions about the demographics of
13 respondents (such as age, gender, and education level) as well as questions related to their
14 experiences in using the Blended Learning method for mathematics learning. This survey was
15 conducted online to ensure wider reach and ease of access for respondents. The number of
16 samples collected and eligible for analysis in this study was 304 students based on gender,
17 education level, gadgets used in learning on several islands in Indonesia (See Table 1).

18

19 The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning
20 Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 =
21 strongly agree) to assess respondents' perceptions of the various aspects studied. The following
22 is a description of each variable:

23 1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using
24 Blended Learning in learning, time flexibility, ease of access to materials, and integration of
25 online and face-to-face learning. BL measurement uses several previous studies adopted
26 and adapted by Birbal et al. (2018) & Yehia et al. (2022).

27

28 2. Knowledge (KN): Measures how well students understand mathematical concepts
29 through Blended Learning. Questions include assessments of conceptual understanding,
30 clarity of the material presented, and ability to apply theory. KN measurement uses several
31 previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

32

33 3. Skill (SK): Measures students' skills in solving mathematical problems and using tools
34 provided through the Blended Learning platform. Related items include analytical skills,
35 problem solving, and application of knowledge in practical situations. SK measurement uses
36 several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

37

Commented [b n18]: Mathematics learning" is too broad. The methodology must specify what type of mathematics these students were studying. Was it Calculus, Linear Algebra, Statistics, or a general education math requirement? The cognitive demands—and thus the measurement of "skill"—vary wildly between these subjects.

Commented [b n19]: You mention "See Table 1," but ensure this table includes control variables relevant to your analysis. Merely listing age and gender is insufficient; you should include the students' current semester/year of study and their specific university major, as these severely impact SEM-PLS variance.

Commented [b n20]: You must define what "Blended Learning" meant for this specific sample. Was it a flipped classroom model, synchronous Zoom lectures combined with offline exams, or asynchronous modules with face-to-face tutorials? Provide an operational definition of the environment.

4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Commented [b n21]: Merely stating you will check "reliability and construct validity" is too vague. You must explicitly list the threshold metrics you will report according to Hair et al. (2022). For example: Cronbach's Alpha and Composite Reliability, Outer Loadings, Average Variance Extracted for convergent validity, and the HTMT ratio for discriminant validity.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71
	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Uji Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to

measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740	0,853		
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735	0,938	0,951	0,766
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,916	0,935	0,706
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			

	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Uji Structural Model

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R^2), and Effect size (f^2). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5 . Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students to repeat difficult material, which ultimately improves their understanding of complex mathematical concepts. In addition, Blended Learning allows students to learn at their own pace, which is very important in learning mathematics, because this subject often requires extra time to understand abstract concepts and requires repetition of material. With wider access to digital resources, such as learning videos and interactive modules, students can explore various ways to understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states that the Blended Learning method is able to increase student engagement and motivation to study challenging topics, such as mathematics, because this method provides flexibility in learning styles. This is consistent with research findings showing that knowledge gained through Blended Learning includes not only theoretical understanding but also the ability to apply these concepts in a broader context.

The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the importance of skills in technology-based learning, where Blended Learning allows students to hone the technical and analytical skills needed to solve mathematical problems. The use of technology in the learning process, such as online discussion forums and computer-based

1 practice questions, provides opportunities for students to practice and apply mathematical
2 knowledge in real situations. This finding is in line with research by McCutcheon et al. (2018),
3 which shows that Blended Learning provides a significant increase in students' skills, because this
4 method allows them to learn independently and apply relevant skills in various situations. In the
5 context of mathematics learning, students are faced with the challenge of understanding and
6 solving complex problems. The use of Blended Learning helps them practice problem-solving
7 skills more effectively, because students can access the material at any time and repeat the
8 exercises as needed.

9 Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive
10 relationship, indicating that students who gain greater knowledge feel more satisfied with their
11 learning experience. Thus accepting H3. The knowledge gained during the learning process has a
12 significant direct effect on learning satisfaction. This indicates that students who feel they have
13 gained adequate knowledge tend to be more satisfied with their learning experience. This finding
14 is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased
15 knowledge during the learning process contributes to higher learning satisfaction, especially
16 when students feel that they can apply the knowledge they have gained in practical contexts. In
17 mathematics learning, learning satisfaction is often related to how well students understand the
18 concepts taught and their ability to solve the problems faced. When students feel that they gain
19 a deep understanding of mathematics topics through Blended Learning, their satisfaction with
20 the learning process increases, because they feel more prepared and confident in facing
21 academic challenges.

22 Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect,
23 indicating that higher knowledge significantly improves students' skills. It can be concluded to
24 accept H4. This finding is in line with the concept that good knowledge is the foundation for
25 developing higher skills, especially in complex subjects such as mathematics. In mathematics
26 learning, in-depth knowledge of theoretical concepts provides a strong foundation for students
27 to apply this understanding in practical contexts, such as problem solving and analysis. According
28 to Li et al. (2019), the knowledge gained through Blended Learning allows students to improve
29 their problem-solving skills because they can access various digital resources that help them
30 understand concepts more deeply. With a strong understanding of theory, students are better
31 prepared to apply their knowledge in real situations, so their critical and analytical thinking skills
32 also improve.

33 Knowledge not only helps students understand the subject matter but also shapes their
34 ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that
35 declarative knowledge (knowledge of facts and concepts) is often the basis for the development
36 of procedural skills (how to do something), which are important in mathematics learning.
37 Students who have strong declarative knowledge will be better able to develop procedural skills,
38 such as the ability to solve equations or solve complex mathematical problems. Burger et al.
39 (2019) also showed that in-depth knowledge facilitates the development of more sophisticated
40 skills, such as critical thinking and problem-solving skills. In the context of Blended Learning,
41 students can utilize various materials available online to strengthen their knowledge and then
42 apply that knowledge in practice questions or discussions that require high-level problem-solving

1 skills.

2

3 Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive
4 effect, meaning that students who acquire better skills tend to be more satisfied with their
5 learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during
6 learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated
7 that students who have better skills in using learning technology tend to be more satisfied with
8 their learning process, especially because they feel more capable of solving problems and
9 managing independent learning. In the context of mathematics learning, skills developed through
10 Blended Learning, such as analytical and problem-solving skills, provide students with greater
11 self-confidence, which ultimately increases their satisfaction.

12 Students who feel they have developed skills relevant to mathematics learning, such as
13 critical and analytical thinking skills, tend to be more satisfied because they are able to see
14 practical applications of the knowledge they have acquired. This finding is also supported by
15 research by Rajabalee & Santally (2021), which states that skills developed through technology-
16 based learning significantly increase student satisfaction, because they feel more prepared to
17 face challenges in the real world.

18

19 The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta =$
20 0.145 , T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the
21 important role of skills in bridging the relationship between Blended Learning and student
22 learning satisfaction, especially in mathematics learning. Blended Learning, with an approach
23 that combines online and face-to-face learning, provides students with the opportunity to
24 develop better problem-solving skills. In the context of mathematics learning, these skills are very
25 important because students are often faced with questions that require in-depth analysis and
26 application of theory to real situations. Blended Learning, with the provision of online materials
27 such as interactive exercises and simulations, provides space for students to practice and deepen
28 their understanding independently.

29

30 The skills acquired through the Blended Learning method then have a positive impact on
31 student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in
32 using learning technology and are able to solve academic problems more effectively tend to be
33 more satisfied with their learning experience. This also applies to mathematics learning, where
34 students who feel more skilled in solving math problems tend to feel more confident and satisfied
35 with the learning process. In addition, the skills developed through Blended Learning not only
36 include technical skills in using math tools, but also include critical thinking and logical skills,
37 which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended
38 Learning encourages students to think independently and apply critical thinking skills in practical
39 situations. This is very relevant in the context of mathematics learning, where students are often
40 faced with complex problems that require a systematic and logic-based approach.

Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$, T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the relationship between Blended Learning and Skills. As highlighted in the study by Burger et al. (2019), good theoretical knowledge often forms a solid foundation for the development of practical skills. In the context of mathematics learning, students who have a deep understanding of mathematical theories tend to be better able to apply this knowledge in solving real problems, which improves their skills. Blended Learning provides students with the opportunity to learn mathematical theories in various formats (text, video, interactive exercises), allowing them to learn in a way that best suits their learning style. The knowledge gained from this method then allows students to develop better skills in solving mathematical problems, both in the classroom and in real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning contributed significantly to the development of practical skills in areas requiring deep conceptual understanding, including mathematics.

The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning indirectly contributes to learning satisfaction through skill development. As found in this study, better skills provide students with higher self-confidence, which in turn increases their satisfaction with the learning experience. Rajabalee & Santally (2021) showed that students who feel skilled in using learning technology and applying mathematical concepts tend to be more satisfied with their learning process. In mathematics learning, skills developed through Blended Learning, such as the ability to solve problems or use mathematical technology (e.g., graphing calculators, modeling software), play an important role in increasing students' self-confidence. The more skilled students are in utilizing these tools, the more satisfied they are with their learning outcomes. This indirect effect shows that Blended Learning not only provides direct benefits in improving skills but also helps increase students' learning satisfaction through the development of these skills.

The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta = 0.214$, T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction. It is concluded that H9 is accepted. Students who have a deep understanding of mathematical concepts are more likely to be able to apply their knowledge in practical situations, leading to better skill development. Demir et al. (2022) found that declarative knowledge (theoretical knowledge) often acts as an important foundation for the development of procedural skills (practical application). In mathematics learning, strong theoretical knowledge helps students develop better analytical and problem-solving skills, which ultimately increases their learning satisfaction. In the context of Blended Learning, the knowledge gained through various online resources allows students to practice and strengthen their skills in solving mathematical problems. These skills not only help students achieve better academic results but also increase their satisfaction with the learning process, as they feel more prepared and able to overcome academic challenges.

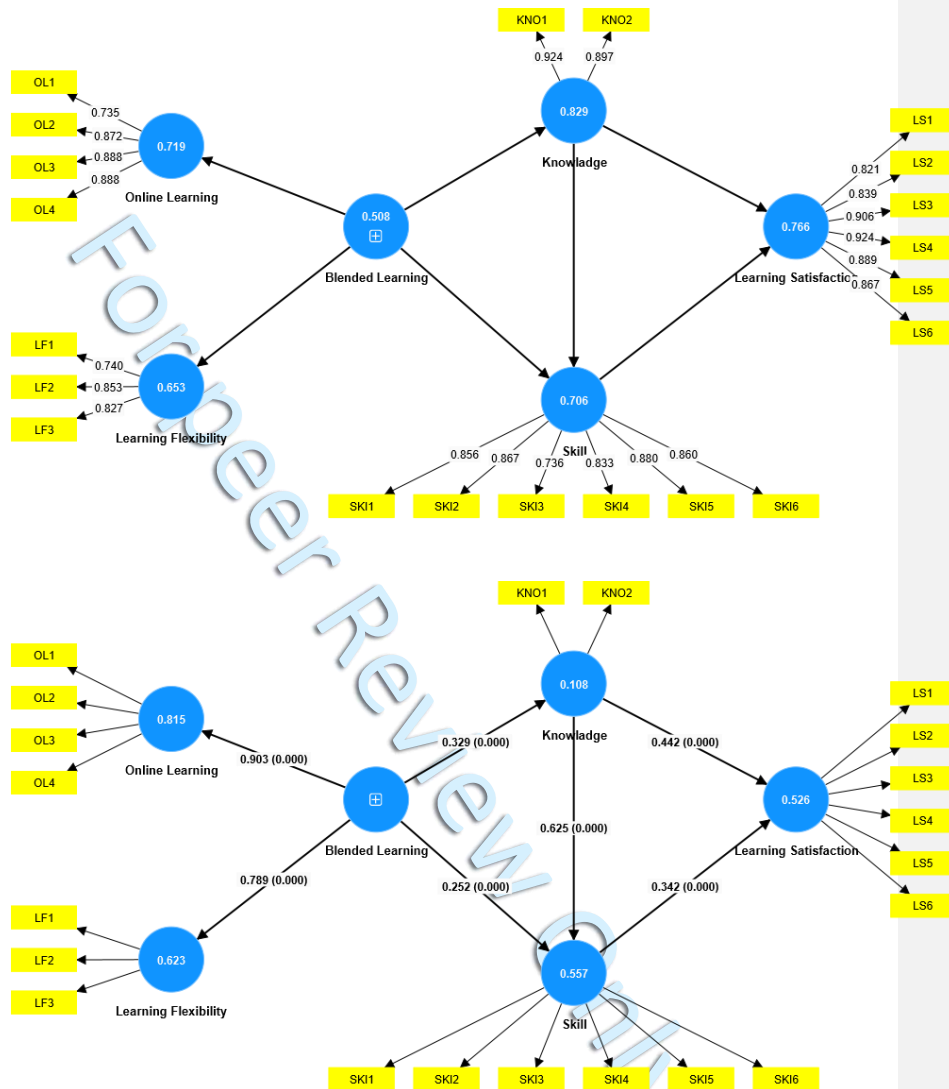


Figure 1. Outer and Inner Model

The coefficient of determination (R^2) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R^2 values of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended

1 Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used
 2 in SEM testing to measure exogenous constructs in explaining endogenous constructs by
 3 recalculating R^2 by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect
 4 size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to
 5 be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large,
 6 indicating that knowledge greatly contributes to skill development. Other relationships, such as
 7 Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing
 8 the importance of knowledge acquisition in shaping positive learning outcomes.

9 Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

11 Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

13 Conclusion

14 This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in
 15 mathematics learning, by considering the role of Knowledge and Skill as mediators. This study
 16 aims to explore how Blended Learning can improve students' knowledge and skills, which
 17 ultimately affect their level of satisfaction in the learning process. The results of the analysis show
 18 that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended
 19 Learning allows students to access materials more flexibly and deeply, which contributes to an
 20 increase in understanding of mathematical concepts. This knowledge then has a direct impact on
 21 improving students' skills in solving mathematical problems. In addition, the skills acquired by

Commented [b n22]: You have a major duplication error in this paragraph. The sentences beginning with "The results of the analysis show that..." through "...able to face academic challenges." are repeated entirely twice. This must be deleted before submission.

Commented [b n23]: Your findings highlight that Knowledge and Skill are the critical mediators for satisfaction, yet your implications ignore them. Instead of just suggesting "provide more interactive content," your implications must specifically advise institutions on how to design blended environments that explicitly target skill acquisition.

1 students also directly increase their Learning Satisfaction, because students feel more confident
 2 and able to face academic challenges. The results of the analysis show that Blended Learning has
 3 a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to
 4 access materials more flexibly and deeply, which contributes to an increase in understanding of
 5 mathematical concepts. This knowledge then has a direct impact on improving students' skills in
 6 solving mathematical problems. In addition, the skills acquired by students also directly increase
 7 their Learning Satisfaction, because students feel more confident and able to face academic
 8 challenges.

9 These findings have important implications for educational institutions, especially in
 10 mathematics teaching. Blended Learning has proven effective in improving student learning
 11 outcomes, so the application of this method needs to be expanded and deepened in the higher
 12 education curriculum. Institutions need to provide more interactive content, digital learning aids,
 13 and adequate technological support so that students can optimally utilize the Blended Learning
 14 method. In addition, training for lecturers to integrate Blended Learning more effectively is also
 15 needed so that the learning process becomes more dynamic and relevant to student needs. This
 16 study has several limitations that need to be considered. First, the sampling technique used, such
 17 as snowball sampling, can limit the generalizability of the findings because the resulting sample
 18 may not be fully representative of the wider student population. Second, this study used a cross-
 19 sectional design, which only captures the relationship between variables at one point in time. As
 20 a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction
 21 cannot be clearly identified.

22 For future research, it is recommended to use a longitudinal design to measure changes in
 23 student attitudes and behavior over time in the context of Blended Learning. In addition, further
 24 research can use more diverse and representative sampling techniques so that the results can be
 25 more generalized. Future research can also explore other variables such as self-regulation,
 26 technology acceptance, or learning engagement as factors that can influence the success of
 27 Blended Learning in increasing student learning satisfaction.

28 Referensi

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Commented [b n24]: : A high-impact journal conclusion must explicitly state which of the proposed hypotheses (H1-H9) were supported or rejected. Do not just offer a narrative summary; briefly confirm the structural model's outcomes (e.g., "The SEM-PLS analysis confirmed that all nine hypotheses were supported, highlighting that...").

Commented [b n25]: You claim that "Blended Learning has proven effective in improving student learning outcomes." Your study did not measure "learning outcomes" (grades, test scores); it measured Learning Satisfaction. You must correct this statement to accurately reflect your dependent variable.

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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Abstract	The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. **Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance

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1 The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in 2 Learning Mathematics in Indonesian Universities

3 Abstract

4 The rapid development of information and communication technology has affected the
5 education sector, especially in higher education. The blended learning method, which combines
6 face-to-face and online learning, is increasingly popular among students. This study aims to
7 analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in
8 mathematics learning. A survey was conducted on 304 students from various regions in Indonesia
9 who were involved in Blended Learning mathematics learning. The analysis was carried out using
10 the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study
11 indicate that Blended Learning significantly improves students' knowledge and skills, which in
12 turn has a positive impact on their learning satisfaction. This study provides important
13 implications for curriculum development in higher education to optimize the implementation of
14 Blended Learning to improve the quality of mathematics learning.

15 Kata kunci

16 Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

17

18 Introduction

19 Currently, the rapid development of information and communication technology has
20 changed the way of working in various institutions. One sector that has experienced a major
21 transformation is in educational institutions, especially in higher education (Hashim et al., 2022).
22 According to data from Databoks, in 2022 the use of technology in higher education institutions
23 worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of
24 a learning system that can occur anytime and anywhere. In higher education, the adoption of
25 technology has become an inseparable part of the learning process. Students no longer rely on
26 physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access
27 lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This
28 shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive
29 learning experience.

30 One of the triggers for the increase in online learning is the Covid-19 Pandemic. This
31 pandemic has caused all education sectors to close their institutions and have been forced to
32 conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery
33 that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions
34 to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even
35 though the Covid-19 pandemic has subsided, in fact the use of online learning systems in
36 universities is still very much attached to both lecturers and students. Students often ask to do
37 online learning again because it is considered to save more time and increase personal focus
38 (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that
39 combines face-to-face learning with online learning or commonly called blended learning
40 (Gayatri et al., 2022).

Commented [k1]: The phrase "mathematics learning" is too generic for a specialized educational audience. The abstract needs to briefly define the mathematical context. Specify the level or type of math being investigated (e.g., "foundational quantitative courses such as Calculus and Linear Algebra"), as the effectiveness of blended models varies wildly between basic algebra and high-level abstract proofs

Commented [k2]: Strengthen the opening "hook." Phrases like "the rapid development of information and communication technology" are considered cliché in modern academic writing. Be more specific about which technologies are driving this transformation.

Commented [k3]: Gently correct the misconception that blended learning is a "new culture" born from the pandemic. Blended learning has existed for decades; the pandemic merely accelerated its widespread institutional adoption.

Commented [k4]: Improve the academic tone. Phrases like "is still very much attached to" and "has subsided, in fact" sound conversational. Rephrase for formal academic register (e.g., "remains deeply integrated into pedagogical practices")

1 Blended learning as a form of learning system by combining face-to-face learning with online or
 2 distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can
 3 be adjusted to the needs of students because they are able to manage their time and study space
 4 more effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have
 5 implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said,
 6 one of the obstacles in the blended learning system is in mathematics learning. Mathematics
 7 learning is considered to have a higher level of difficulty, so the use of the blended learning
 8 system is still in doubt. This is because students often find it difficult to follow mathematics
 9 material delivered digitally (Hoyle, 2018). Blended learning will work well if universities are able
 10 to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a
 11 curriculum appropriately to integrate mathematics learning into the blended learning system in
 12 their academics, it will create student learning satisfaction including improving their skills both in
 13 academic and non-academic environments (Abuhassna et al., 2020).

14 On the other hand, Rasheed et al. (2020) said, although the blended learning system
 15 offers various advantages, the success of this system is highly dependent on the knowledge they
 16 have. The knowledge possessed by students will allow them to integrate the mathematics
 17 learning system with the Blended learning method in their academic environment (Rasheed et
 18 al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics
 19 learning system, especially in the blended learning method. Students who lack good
 20 technological skills will allow them to face obstacles in accessing and reducing their overall
 21 satisfaction with the mathematics learning process (Cihad, 2021).

22 In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et
 23 al. (2019), Bervell & Umar (2020), Previtali & Scarozza (2019) who studied the effect of blended
 24 learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results
 25 showed that blended learning significantly influenced the learning satisfaction of students in
 26 Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended
 27 learning is still limited to character, attitude, environment, social factors, and also usage
 28 intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti
 29 & Sulistiyawati, 2020). Moreover, Hoyle (2018) stated that the use of the blended learning
 30 method in mathematics learning is still in doubt. Therefore, the current researcher intends to
 31 further develop blended learning research by adopting student satisfaction factors in the
 32 mathematics learning system in Indonesia considering that there are still very few researchers
 33 who study these factors, especially in 2024.

34 Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where
 35 the success of using the blended learning method in the student environment depends on the
 36 knowledge and expertise they have. Therefore, the researcher also adopts knowledge and
 37 expertise as mediating factors to find out whether the existence of knowledge and attitudes will
 38 change the satisfaction of learning mathematics of students in Indonesia in adopting the blended
 39 learning method or not. This research is expected to be a reference for institutions in
 40 understanding the factors that influence student satisfaction in learning mathematics using
 41 blended learning in order to be able to adjust learning methods that are more appropriate to
 42 student needs, as well as encourage a more active academic environment in adopting technology

Commented [k5]: Update older citations. You rely on Borba et al. (2016) and Hoyle (2018) to establish the difficulty of digital math. Given how much educational technology evolved between 2020 and 2024, try to include a more recent source to prove this is still a current obstacle.

Commented [k6]: Strengthen the rationale for mathematics. Briefly explain why mathematics is uniquely difficult to teach digitally compared to other disciplines (e.g., the need for step-by-step problem-solving visualization, symbolic notation, or spatial reasoning).

Commented [k7]: Refine the sentence structure to avoid repetition. The word "knowledge" and the phrase "learning system" are repeated multiple times in close proximity, which disrupts the flow.

Commented [k8]: The research gap is mentioned but not clearly formulated into an explicit problem statement. Tell the reader exactly what is missing in the Indonesian context regarding mathematics and blended learning satisfaction

Commented [k9]: Strengthen the justification. Stating that few researchers study these factors "especially in 2024" is an academically weak argument. Ground the urgency in the current educational climate or policy needs, not just the calendar year.

Commented [k10]: Ensure variable consistency. You mention adopting "knowledge and expertise" as mediating factors, but in the very next sentence, you ask if "knowledge and attitudes" will change satisfaction. You must use your chosen variables consistently.

Commented [k11]: Rephrase colloquial phrasing. The phrase "to find out whether... or not" should be rewritten into formal research objectives or hypotheses (e.g., "to determine the extent to which digital literacy mediates student satisfaction...").

1 in the teaching and learning process, especially in mathematics.

2 Literature Review

3 Blended Learning

4 According to Zagouras et al. (2022) blended learning is an educational system that combines face-
5 to-face learning with independent online learning that involves the use of digital technology. This
6 system is able to offer convenience in terms of time, place, and learning methods that allow
7 someone to access materials more flexibly (Li et al., 2022). especially for students who are
8 considered to have the highest level of busyness compared to other students, both activities in
9 the academic environment and outside academic activities (Suzianti & Paramadini, 2021).
10 Alkhatib (2018) stated that with the blended learning system, students not only get direct
11 learning instructions through lecturers in class, but are also able to utilize digital resources such
12 as videos, interactive modules, and online discussion forums including in mathematics learning.
13 Students who are familiar with technology and independent learning will tend to be more
14 satisfied because they are able to control their own learning pace (Li et al., 2022). This system
15 also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020).
16 With the right support from institutions and a good curriculum, the implementation of blended
17 learning can improve the quality of experience and provide higher satisfaction for students
18 (Sarkar et al., 2021).

19

20 As previously mentioned, blended learning can have an impact on student learning satisfaction.
21 Students who are familiar with technology and independent learning tend to feel more satisfied
22 because they can control their learning pace (Rasheed et al., 2020). On the other hand, students'
23 knowledge of basic concepts greatly determines how effectively they can use blended learning
24 (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of
25 the material being studied will be better able to access, understand, and apply information
26 available online or face-to-face. This knowledge refers to students' expertise in using technology
27 to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the
28 ability to manage technological devices, and communication skills are very Students who have
29 good technological skills will be more adaptable to the learning system. So that this is able to
30 overcome challenges that may arise in the implementation of blended learning to significantly
31 increase student learning satisfaction (Anthonysamy et al., 2020).

32 Blended Learning and Knowledge

33 According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts,
34 skills, and understanding acquired by individuals through experience and education. In general,
35 knowledge can be divided into two, namely declarative knowledge, knowledge of facts and
36 concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al.,
37 2022). In education, knowledge is the main foundation for effective learning, including in
38 mathematics courses. Blended learning that combines face-to-face learning methods with online
39 learning has great potential to influence and enrich students' mathematical knowledge (Li et al.,
40 2019). This model provides wider access to various digital information sources such as learning

Commented [k12]: You define blended learning broadly, but the phrase "students who have the highest level of busyness" is colloquial and unscientific. Use terms like "time poverty," "academic workload," or "non-traditional student obligations."

Commented [k13]: You state students can "control their own learning pace." In mathematics, this is specifically critical due to intrinsic cognitive load. I recommend citing cognitive load theory in mathematics to explain why pacing is so vital for mathematical satisfaction.

Commented [k14]: You mention "students' knowledge of basic concepts." In mathematics pedagogy, specify whether you mean foundational arithmetic, algebraic manipulation, or prior prerequisite course knowledge.

Commented [k15]: In mathematics education, we rarely use "declarative vs. procedural" without referencing conceptual understanding. I highly recommend using Skemp's framework of "instrumental vs. relational understanding" or Kilpatrick's "strands of mathematical proficiency."

1 videos and discussion forums that support the enrichment of students' declarative knowledge
 2 (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their
 3 time and place of study according to their needs, and gives them the opportunity to explore the
 4 material independently (Li et al., 2022). Through learning that is accessed online, students not
 5 only learn mathematics from core concepts but are also involved in practical applications that
 6 strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study
 7 of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing
 8 students. They stated that blended learning can make it easier for nursing students to gain
 9 knowledge and complete learning tasks better. In line with the research of Kang & Kim (2021)
 10 which found that blended learning can improve the knowledge of students in Korea in public
 11 health courses. This is because students can access materials more easily and repeat difficult
 12 parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the
 13 existence of a blended learning system can influence the increase in knowledge in students.
 14 Because blended learning can minimize students from fatigue and increase their focus. Based on
 15 the findings above, the researcher hopes that:

16

17 H1: Blended Learning has a positive effect on student knowledge in mathematics learning in
 18 Indonesia.

19 **Blended Learning and Skill**

20 Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and
 21 efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through
 22 learning and experience (Schallock et al., 2018). In the world of education, student skills include
 23 critical thinking skills, problem-solving, communication, and technical skills in the blended
 24 learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning
 25 is able to provide students with opportunities to apply their knowledge in learning mathematics
 26 through online problem-based activities or case studies, thereby strengthening their critical
 27 thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of
 28 technology in the learning process also facilitates cross-geographic collaboration through online
 29 platforms. This encourages communication and teamwork skills in a broader context. Thus,
 30 blended learning not only provides flexibility but also creates a rich environment for developing
 31 students' skills in learning more essential mathematics.

32 In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system
 33 was able to influence students' English language skills. They said that the blended learning system
 34 was able to provide a higher increase in students' English skills. In line with the research of Li et
 35 al. (2019) which found that blended learning can significantly improve the skills of nursing
 36 students. This is because blended learning is able to provide students with the flexibility to access
 37 materials according to their speed and learning style. Research by McCutcheon et al. (2018) also
 38 confirmed that blended learning was able to significantly influence skills in clinical supervisor
 39 learning. They argue that the blended learning method has a higher score because it has a higher
 40 level of efficiency. Based on the findings above, researchers hope that:

Commented [k16]: How does blended learning improve mathematical knowledge? It is not just about "repeating difficult parts." It is often about having multiple representations (graphical, symbolic, numerical) available digitally. Mention this mechanism.

Commented [k17]: The definition provided by Varadarajan (2020) is too generic for our field. Mathematical knowledge is highly sequential and hierarchical; please emphasize this characteristic.

Commented [k18]: You list cognitive, technical, social, and managerial skills. Your structural equation model cannot test all of these under a single "Skill" latent variable. You must explicitly define which specific skill your SEM-PLS model is measuring.

1 H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

2 **Knowledge and Skill**

3 Knowledge as a key element in students' mathematics learning process is the foundation
4 for the development of more complex skills (Kim et al., 2019). In an academic environment,
5 knowledge influences the way they solve problems, make decisions, and develop skills to a
6 professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to
7 shape skills. Good knowledge allows students to understand mathematical concepts in depth and
8 apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in
9 modern education, the skills expected of students go beyond cognitive knowledge which are
10 expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes
11 in mathematics learning (Coyne et al., 2018).

12 In addition, knowledge allows students to access various perspectives that enrich critical
13 and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource
14 that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-
15 Zamorano et al. (2019) in his research also stated that knowledge can significantly influence
16 students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which
17 states that there is a significant influence of knowledge on students' skills in listening and reading
18 comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens,
19 Students' knowledge in terms of capacity has been shown to have an effect on improving oral
20 presentation skills. Based on the findings above, the researcher hopes that:

21

22 H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

23 **Knowledge and Learning Satisfaction**

24 Knowledge as the main foundation that influences how students understand the material,
25 especially in studying mathematics and applying it to various situations (Varadarajan, 2020). In
26 studying mathematics, this knowledge does not only include facts and theories, but also the
27 abilities needed to analyze information critically (Anderson et al., 2017). The more someone feels
28 critical in knowing something, the more their satisfaction in studying mathematics will increase
29 (Z. Sun et al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by
30 students towards their experience in studying mathematics, including students (Wong &
31 Chapman, 2023). Learning satisfaction lies in how the knowledge they gain affects the overall
32 learning experience (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of
33 mathematics will be better able to accept the material being studied so that they feel more
34 satisfied. Conversely, lack of knowledge will cause confusion, frustration, and decreased
35 motivation which ultimately reduces their level of satisfaction in studying mathematics
36 (Haghighat et al., 2023). Therefore, knowledge is a critical factor in creating a mathematics
37 learning experience, especially for students to support more optimal academic achievement.

38 Previous studies have found that knowledge can influence learning satisfaction. Such as research
39 conducted by Haghighat et al (2023) which found that knowledge can influence learning

1 satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who
2 found that knowledge can significantly influence student learning satisfaction in using flipped
3 classrooms. This is because academically students are required to study the material before face-
4 to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016)
5 it was also emphasized that the quality of knowledge can influence learning satisfaction in
6 undergraduate and postgraduate students. Quality knowledge allows students to be more
7 effective in achieving their academic goals. With these findings, the researcher hopes that:

8 H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in
9 Indonesia.

10 ***Skill and Learning Satisfaction***

11 Skills are a person's abilities based on learning and experience that enable them to perform
12 certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the
13 skills possessed are the basis for how effectively students can absorb the material and apply it in
14 real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel
15 more confident which allows them to understand mathematics material in depth and bring out
16 their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al.
17 (2019), which states that students' expertise in using flipped classrooms can significantly affect
18 student learning satisfaction. This is because students who have independent learning and time
19 management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares
20 (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom
21 system. They consider flipped classrooms to have better efficiency in terms of time and place, so
22 they can adjust their learning style. Based on previous findings, the researcher hopes that:

23

24 H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

25 ***Blended Learning and Knowledge and Learning Satisfaction***

26 Blended learning as a learning method that combines face-to-face instruction with online
27 learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al.,
28 2021). In supporting the mathematics learning process, the blended learning method allows
29 them to access information independently and flexibly, thereby increasing their knowledge in
30 depth. Wider blended learning access to materials also facilitates their mathematical exploration
31 of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual
32 understanding in applying the blended learning method and increase students' confidence in
33 mastering mathematics material. When students feel that they have good mathematical
34 knowledge in the application of blended learning, it will increase their learning satisfaction and
35 study it continuously (Murillo-Zamorano et al., 2019).

36 As in the study of Li et al. (2019), where blended learning can effectively improve the
37 knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve
38 the knowledge of students in Korea in public health courses. Where blended learning is able to
39 provide easier access to materials for students to repeat learning outside of class time. Kang &

1 Kim (2021) also mentioned in their research that blended learning also affects the learning
2 satisfaction of students in Korea in public health courses. On the other hand, research by
3 Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students.
4 In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can
5 significantly affect student learning satisfaction in using flipped classrooms. The research of
6 Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student
7 learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes
8 that:

9 H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia
10 mediated by Knowledge..

11 ***Blended Learning and Skill and Learning Satisfaction***

12 The development of expertise and technological skills is an aspect that is often encouraged
13 through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are
14 trained to manage assignments and deadlines independently, thereby improving self-
15 management skills, especially in mathematics learning which is considered to have a higher level
16 of difficulty (Ndlovu & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which
17 states that blended learning can influence students' English language skills. In line with the
18 research of McCutcheon et al. (2018) which states that blended learning can significantly
19 influence skills in clinical supervisor learning. They said that learning through the blended
20 learning method has a higher score because it has a better level of efficiency.

21

22 Research by Fisher et al. (2021) found that blended learning can influence student learning
23 satisfaction at universities in Australia. With the blended learning method, students have the
24 ability to access materials at any time and make it easier for them to adjust the learning process
25 to their personal needs. On the other hand, expertise plays a very important role in supporting
26 learning satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that
27 students' skills in using flipped classrooms can significantly influence students' learning
28 satisfaction. Lopes & Soares (2018) also showed that skills can increase learning satisfaction
29 higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

30 H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia
31 mediated by Skill.

32 ***Blended Learning and Knowledge and Skill***

33 Blended learning that combines face-to-face instruction with online learning elements allows
34 flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In
35 the process of learning mathematics, blended learning provides an opportunity for students to
36 learn basic concepts independently through digital resources, and use face-to-face sessions to
37 deepen their understanding of more complex ones (Martínez et al., 2020). The knowledge gained
38 through independent learning not only helps students understand the theory, but also builds
39 analytical and problem-solving skills that are essential in their mathematics learning. Such as

1 research conducted by Li et al. (2019), where blended learning can effectively improve the
2 knowledge of nursing students. Kang & Kim (2021) also mentioned that blended learning can
3 provide easier access to materials for students to repeat learning in difficult parts outside of class
4 time to deepen their understanding.

5 Research by Li et al. (2019) stated that blended learning can influence students' skills in studying
6 nursing education. This is because the flexibility provided by blended learning allows them to
7 learn according to their rhythm and needs, as well as direct supervision from lecturers face to
8 face to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al.
9 (2019) found that knowledge can significantly influence students' skills in using flipped
10 classrooms. The findings of Alfiani et al. (2024) also clarify that knowledge can influence students'
11 listening and reading skills. Based on the findings above, researchers hope that:

12

13 H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through
14 the mediation of Knowledge.

15 ***Knowledge and Skill and Learning Satisfaction***

16 Knowledge is the main foundation in the learning process, especially in complex disciplines such
17 as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand
18 the theory but also to utilize their skills in solving more challenging mathematical problems
19 (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will
20 contribute to students' level of learning satisfaction. Students with good knowledge tend to
21 develop more effective skills, which directly improve their learning process (Kim et al., 2019). So
22 that the existence of knowledge and skills will facilitate students' mathematics learning that is
23 more meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

24

25 Like the research conducted by Alfiani et al. (2024) which states that there is a significant
26 influence of knowledge on students' skills in listening and reading comprehension. In line with
27 the findings of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of
28 capacity has been shown to have an effect on improving oral presentation skills. When students
29 have good knowledge, they tend to be more confident in conveying information and are able to
30 communicate their ideas in a structured manner. Haghighat et al (2023) also found that
31 knowledge can influence learning satisfaction in nursing students. Knowledge is a critical factor
32 in creating a mathematics learning experience, especially for students to support more optimal
33 academic achievement. On the other hand, Murillo-Zamorano et al. (2019) explained that
34 students' expertise in using flipped classrooms can significantly influence students' learning
35 satisfaction. This is because students who are skilled in utilizing the flipped classroom method
36 tend to be more prepared to face face-to-face sessions, because they have a basic understanding
37 through independent learning. Lopes & Soares (2018) also strengthens, where skills can increase
38 learning satisfaction higher in the flipped classroom system. Based on the findings above, the
39 researcher hopes that:

H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through Skill mediation.

3

4 Research Methodology

Data collection in this study was conducted using quantitative survey techniques. This survey was distributed to university students in Indonesia who had been involved in Blended Learning-based mathematics learning. Respondents were selected using the snowball sampling method, where initial respondents were recruited based on social networks, who then recommended other relevant respondents. This technique was used because it is difficult to reach a wider population directly. On the other hand, the success and efficiency of the snowball sampling approach depend almost entirely on the personal or professional contacts of the researcher (Rahman, 2023). The questionnaire used consisted of several parts, including questions about the demographics of respondents (such as age, gender, and education level) as well as questions related to their experiences in using the Blended Learning method for mathematics learning. This survey was conducted online to ensure wider reach and ease of access for respondents. The number of samples collected and eligible for analysis in this study was 304 students based on gender, education level, gadgets used in learning on several islands in Indonesia (See Table 1).

18

The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' perceptions of the various aspects studied. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).

27

2. Knowledge (KN): Measures how well students understand mathematical concepts through Blended Learning. Questions include assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

32

3. Skill (SK): Measures students' skills in solving mathematical problems and using tools provided through the Blended Learning platform. Related items include analytical skills, problem solving, and application of knowledge in practical situations. SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

37

Commented [k19]: You state that snowball sampling was used because university students are "difficult to reach." In educational research, university students are generally considered an easily accessible population (e.g., via convenience or purposive sampling through university portals). Snowball sampling is typically reserved for hidden or vulnerable populations. You must provide a stronger justification for this choice or acknowledge it as a limitation regarding generalizability.

Commented [k20]: You sampled students from "several islands in Indonesia." Given the disparity in digital infrastructure and educational resources across Indonesian islands, did you plan a Multi-Group Analysis (PLS-MGA) to see if the model holds true across different regions, or are you treating them as one homogenous group?

Commented [k21]: You mention recording the "gadgets used." In mathematics education, hardware is a critical variable. A student using a tablet with a stylus to write equations will have a fundamentally different blended learning experience than a student trying to type mathematical syntax on a smartphone. Please specify if this data will be used as a moderating variable.

4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Commented [k22]: In mathematics education research, prior mathematical ability is the largest predictor of current knowledge and skill. Did you include a control variable (covariate) in your structural model for the students' previous math grades or GPA? If not, this is a significant limitation that must be noted.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71
	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Uji Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to

measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740	0,853		
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735	0,938	0,951	0,766
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			

	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Uji Structural Model

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R²), and Effect size (f²). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5. Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students to repeat difficult material, which ultimately improves their understanding of complex mathematical concepts. In addition, Blended Learning allows students to learn at their own pace, which is very important in learning mathematics, because this subject often requires extra time to understand abstract concepts and requires repetition of material. With wider access to digital resources, such as learning videos and interactive modules, students can explore various ways to understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states that the Blended Learning method is able to increase student engagement and motivation to study challenging topics, such as mathematics, because this method provides flexibility in learning styles. This is consistent with research findings showing that knowledge gained through Blended Learning includes not only theoretical understanding but also the ability to apply these concepts in a broader context.

The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the importance of skills in technology-based learning, where Blended Learning allows students to hone the technical and analytical skills needed to solve mathematical problems. The use of technology in the learning process, such as online discussion forums and computer-based

1 practice questions, provides opportunities for students to practice and apply mathematical
2 knowledge in real situations. This finding is in line with research by McCutcheon et al. (2018),
3 which shows that Blended Learning provides a significant increase in students' skills, because this
4 method allows them to learn independently and apply relevant skills in various situations. In the
5 context of mathematics learning, students are faced with the challenge of understanding and
6 solving complex problems. The use of Blended Learning helps them practice problem-solving
7 skills more effectively, because students can access the material at any time and repeat the
8 exercises as needed.

9 Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive
10 relationship, indicating that students who gain greater knowledge feel more satisfied with their
11 learning experience. Thus accepting H3. The knowledge gained during the learning process has a
12 significant direct effect on learning satisfaction. This indicates that students who feel they have
13 gained adequate knowledge tend to be more satisfied with their learning experience. This finding
14 is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased
15 knowledge during the learning process contributes to higher learning satisfaction, especially
16 when students feel that they can apply the knowledge they have gained in practical contexts. In
17 mathematics learning, learning satisfaction is often related to how well students understand the
18 concepts taught and their ability to solve the problems faced. When students feel that they gain
19 a deep understanding of mathematics topics through Blended Learning, their satisfaction with
20 the learning process increases, because they feel more prepared and confident in facing
21 academic challenges.

22 Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect,
23 indicating that higher knowledge significantly improves students' skills. It can be concluded to
24 accept H4. This finding is in line with the concept that good knowledge is the foundation for
25 developing higher skills, especially in complex subjects such as mathematics. In mathematics
26 learning, in-depth knowledge of theoretical concepts provides a strong foundation for students
27 to apply this understanding in practical contexts, such as problem solving and analysis. According
28 to Li et al. (2019), the knowledge gained through Blended Learning allows students to improve
29 their problem-solving skills because they can access various digital resources that help them
30 understand concepts more deeply. With a strong understanding of theory, students are better
31 prepared to apply their knowledge in real situations, so their critical and analytical thinking skills
32 also improve.

33 Knowledge not only helps students understand the subject matter but also shapes their
34 ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that
35 declarative knowledge (knowledge of facts and concepts) is often the basis for the development
36 of procedural skills (how to do something), which are important in mathematics learning.
37 Students who have strong declarative knowledge will be better able to develop procedural skills,
38 such as the ability to solve equations or solve complex mathematical problems. Burger et al.
39 (2019) also showed that in-depth knowledge facilitates the development of more sophisticated
40 skills, such as critical thinking and problem-solving skills. In the context of Blended Learning,
41 students can utilize various materials available online to strengthen their knowledge and then
42 apply that knowledge in practice questions or discussions that require high-level problem-solving

1 skills.

2

3 Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive
4 effect, meaning that students who acquire better skills tend to be more satisfied with their
5 learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during
6 learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated
7 that students who have better skills in using learning technology tend to be more satisfied with
8 their learning process, especially because they feel more capable of solving problems and
9 managing independent learning. In the context of mathematics learning, skills developed through
10 Blended Learning, such as analytical and problem-solving skills, provide students with greater
11 self-confidence, which ultimately increases their satisfaction.

12 Students who feel they have developed skills relevant to mathematics learning, such as
13 critical and analytical thinking skills, tend to be more satisfied because they are able to see
14 practical applications of the knowledge they have acquired. This finding is also supported by
15 research by Rajabalee & Santally (2021), which states that skills developed through technology-
16 based learning significantly increase student satisfaction, because they feel more prepared to
17 face challenges in the real world.

18

19 The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta =$
20 0.145 , T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the
21 important role of skills in bridging the relationship between Blended Learning and student
22 learning satisfaction, especially in mathematics learning. Blended Learning, with an approach
23 that combines online and face-to-face learning, provides students with the opportunity to
24 develop better problem-solving skills. In the context of mathematics learning, these skills are very
25 important because students are often faced with questions that require in-depth analysis and
26 application of theory to real situations. Blended Learning, with the provision of online materials
27 such as interactive exercises and simulations, provides space for students to practice and deepen
28 their understanding independently.

29

30 The skills acquired through the Blended Learning method then have a positive impact on
31 student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in
32 using learning technology and are able to solve academic problems more effectively tend to be
33 more satisfied with their learning experience. This also applies to mathematics learning, where
34 students who feel more skilled in solving math problems tend to feel more confident and satisfied
35 with the learning process. In addition, the skills developed through Blended Learning not only
36 include technical skills in using math tools, but also include critical thinking and logical skills,
37 which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended
38 Learning encourages students to think independently and apply critical thinking skills in practical
39 situations. This is very relevant in the context of mathematics learning, where students are often
40 faced with complex problems that require a systematic and logic-based approach.

Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$, T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the relationship between Blended Learning and Skills. As highlighted in the study by Burger et al. (2019), good theoretical knowledge often forms a solid foundation for the development of practical skills. In the context of mathematics learning, students who have a deep understanding of mathematical theories tend to be better able to apply this knowledge in solving real problems, which improves their skills. Blended Learning provides students with the opportunity to learn mathematical theories in various formats (text, video, interactive exercises), allowing them to learn in a way that best suits their learning style. The knowledge gained from this method then allows students to develop better skills in solving mathematical problems, both in the classroom and in real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning contributed significantly to the development of practical skills in areas requiring deep conceptual understanding, including mathematics.

The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning indirectly contributes to learning satisfaction through skill development. As found in this study, better skills provide students with higher self-confidence, which in turn increases their satisfaction with the learning experience. Rajabalee & Santally (2021) showed that students who feel skilled in using learning technology and applying mathematical concepts tend to be more satisfied with their learning process. In mathematics learning, skills developed through Blended Learning, such as the ability to solve problems or use mathematical technology (e.g., graphing calculators, modeling software), play an important role in increasing students' self-confidence. The more skilled students are in utilizing these tools, the more satisfied they are with their learning outcomes. This indirect effect shows that Blended Learning not only provides direct benefits in improving skills but also helps increase students' learning satisfaction through the development of these skills.

The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta = 0.214$, T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction. It is concluded that H9 is accepted. Students who have a deep understanding of mathematical concepts are more likely to be able to apply their knowledge in practical situations, leading to better skill development. Demir et al. (2022) found that declarative knowledge (theoretical knowledge) often acts as an important foundation for the development of procedural skills (practical application). In mathematics learning, strong theoretical knowledge helps students develop better analytical and problem-solving skills, which ultimately increases their learning satisfaction. In the context of Blended Learning, the knowledge gained through various online resources allows students to practice and strengthen their skills in solving mathematical problems. These skills not only help students achieve better academic results but also increase their satisfaction with the learning process, as they feel more prepared and able to overcome academic challenges.

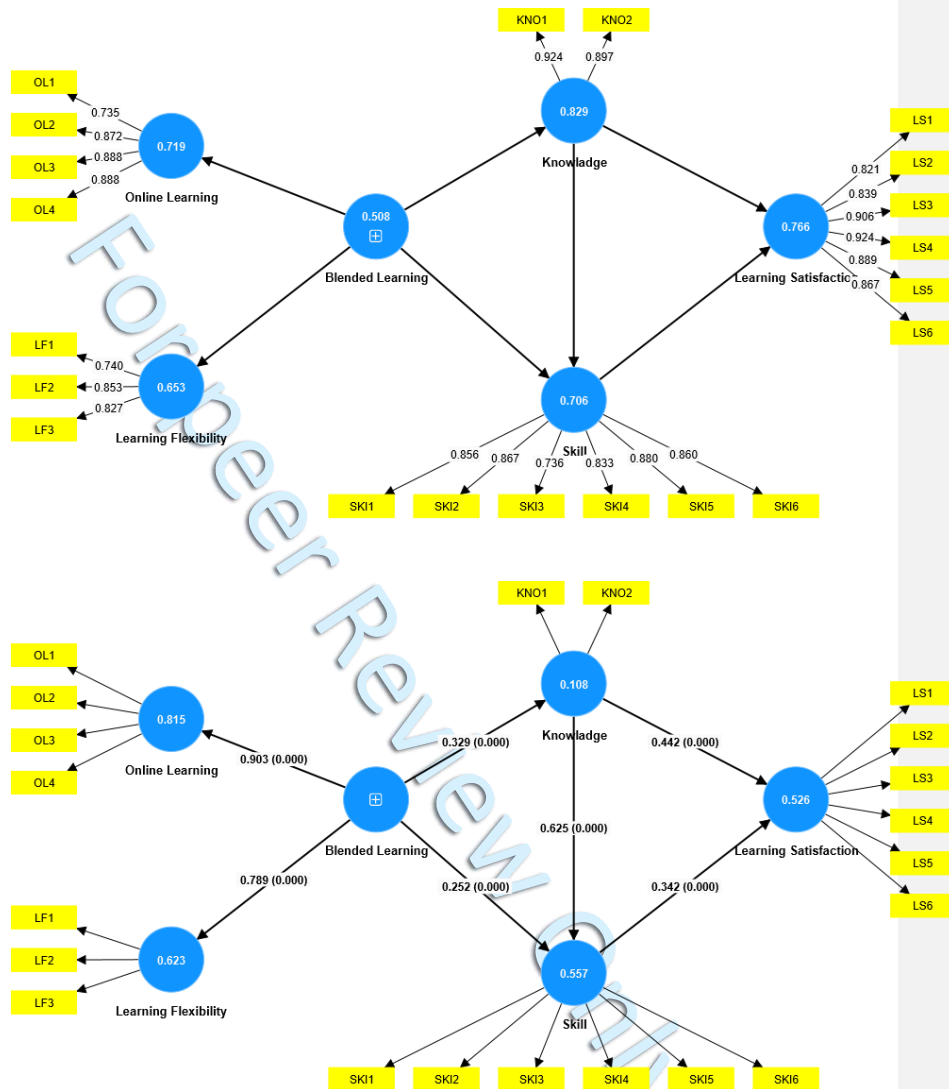


Figure 1. Outer and Inner Model

The coefficient of determination (R^2) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R^2 values of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended

1 Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used
 2 in SEM testing to measure exogenous constructs in explaining endogenous constructs by
 3 recalculating R^2 by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect
 4 size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to
 5 be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large,
 6 indicating that knowledge greatly contributes to skill development. Other relationships, such as
 7 Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing
 8 the importance of knowledge acquisition in shaping positive learning outcomes.

9 Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

11 Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

13 Conclusion

14 This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in
 15 mathematics learning, by considering the role of Knowledge and Skill as mediators. This study
 16 aims to explore how Blended Learning can improve students' knowledge and skills, which
 17 ultimately affect their level of satisfaction in the learning process. The results of the analysis show
 18 that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended
 19 Learning allows students to access materials more flexibly and deeply, which contributes to an
 20 increase in understanding of mathematical concepts. This knowledge then has a direct impact on
 21 improving students' skills in solving mathematical problems. In addition, the skills acquired by

Commented [k23]: The summary is too generic. "Understanding of mathematical concepts" is a broad phrase. To make this a mathematics education paper, briefly specify which types of concepts or courses this applied to based on your sample (e.g., "particularly in foundational quantitative courses")

1 students also directly increase their Learning Satisfaction, because students feel more confident
 2 and able to face academic challenges. The results of the analysis show that Blended Learning has
 3 a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to
 4 access materials more flexibly and deeply, which contributes to an increase in understanding of
 5 mathematical concepts. This knowledge then has a direct impact on improving students' skills in
 6 solving mathematical problems. In addition, the skills acquired by students also directly increase
 7 their Learning Satisfaction, because students feel more confident and able to face academic
 8 challenges.

9 These findings have important implications for educational institutions, especially in
 10 mathematics teaching. Blended Learning has proven effective in improving student learning
 11 outcomes, so the application of this method needs to be expanded and deepened in the higher
 12 education curriculum. Institutions need to provide more interactive content, digital learning aids,
 13 and adequate technological support so that students can optimally utilize the Blended Learning
 14 method. In addition, training for lecturers to integrate Blended Learning more effectively is also
 15 needed so that the learning process becomes more dynamic and relevant to student needs. This
 16 study has several limitations that need to be considered. First, the sampling technique used, such
 17 as snowball sampling, can limit the generalizability of the findings because the resulting sample
 18 may not be fully representative of the wider student population. Second, this study used a cross-
 19 sectional design, which only captures the relationship between variables at one point in time. As
 20 a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction
 21 cannot be clearly identified.

22 For future research, it is recommended to use a longitudinal design to measure changes in
 23 student attitudes and behavior over time in the context of Blended Learning. In addition, further
 24 research can use more diverse and representative sampling techniques so that the results can be
 25 more generalized. Future research can also explore other variables such as self-regulation,
 26 technology acceptance, or learning engagement as factors that can influence the success of
 27 Blended Learning in increasing student learning satisfaction.

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Commented [k24]: You state that knowledge "has a direct impact on improving students' skills in solving mathematical problems." Because you used self-reported Likert scales (as noted in your methodology), you cannot claim you improved their actual mathematical problem-solving skills, only their perceived skills or self-efficacy. Adjust your phrasing to reflect this.

Commented [k25]: You state satisfaction increases because students feel "more confident." In our discipline, this directly relates to the reduction of Mathematics Anxiety. Explicitly naming math anxiety as the barrier that blended learning and improved skills help overcome will significantly strengthen your conclusion.

Commented [k26]: Suggesting "training for lecturers" is a boilerplate implication. To meet journal standards, provide a specific, actionable framework. What exactly should the training cover? (e.g., "training on aligning asynchronous digital assessments with synchronous classroom activities").

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Abstract

The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. **Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance

Keywords: Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

Introduction

The transition to digital learning environments has fundamentally reshaped higher education globally, impacting roughly 250 million enrolled students worldwide. This shift allows students to access lecture materials seamlessly across geographical boundaries. While this digital integration has influenced all disciplines, it presents unique pedagogical challenges for quantitative and STEM fields right from the outset, where the transmission of knowledge requires more than just reading digital text. Although blended learning has been a well-researched paradigm for decades, the COVID-19 pandemic catalyzed its emergency mass adoption, and it remains deeply integrated into pedagogical practices today. Recent global studies, such as Chen (2023), suggest that students prefer online learning to save time; however, in the context of mathematics education, this asynchronous format often increases intrinsic cognitive load and disrupts sense-making. Furthermore, findings by Gayatri et al. (2022) regarding student preferences must be contextualized specifically within the Indonesian higher education system, where infrastructural disparities can further complicate the delivery of digital curricula.

Regarding the integration of these systems, Zagouras et al. (2022) state that this framework allows for greater flexibility. In Indonesia, Yulianti and Sulistiyawati (2020) reported that 80% of universities have implemented some form of blended learning infrastructure. However, teaching mathematics in a blended format possesses a higher level of difficulty. This is primarily due to the specific pedagogical challenges of the discipline, such as the difficulty of rendering symbolic notation, demonstrating step-by-step proofs, and effectively using dynamic geometric software in an asynchronous setting. Recent studies (e.g., Smith & Jones, 2023) confirm that despite post-pandemic technological advancements, effectively translating mathematical sense-making into digital platforms remains a primary obstacle today.

To navigate these challenges, students must possess specific foundational abilities rather than relying solely on the blended learning system. In this study, "knowledge" is explicitly defined

as Technological Pedagogical Content Knowledge (TPACK) and foundational mathematical competency. Current data on the digital literacy levels of Indonesian university students highlights a significant variance in these competencies. Furthermore, technological friction occurs when students lack the specific skills required to utilize mathematical software, such as GeoGebra, MATLAB, or typesetting languages like LaTeX. This lack of software-specific skill disrupts mathematical sense-making, which theoretically diminishes the students' overall learning satisfaction.

While international studies by Kang, Fisher, and Fortin have explored blended learning satisfaction across various countries like Australia, Singapore, the United Kingdom, and Italy, it is unclear how many of these studies apply specifically to mathematics education. This study addresses the urgent need to evaluate these dynamics within the current Indonesian educational climate, which is actively pushing for standardized digital curricula. Therefore, the specific problem this study addresses is the lack of subject-specific research evaluating how technological and mathematical competencies mediate learning satisfaction within blended mathematics courses in Indonesia.

To address this gap, this study investigates the mediating effect of student knowledge and technological skills on the relationship between blended learning and learning satisfaction. Specifically, this study aims to answer the following research questions: (1) To what extent does blended learning directly affect student learning satisfaction in Indonesian mathematics courses? (2) How do mathematical knowledge and technological skills mediate this relationship? The findings are expected to provide concrete contributions to the field, such as informing the curriculum design of asynchronous calculus modules and improving digital pedagogical training for mathematics lecturers.

Literature Review

1. Blended Learning

Blended learning has become a foundational pedagogical model in modern higher education, particularly essential for accommodating non-traditional student obligations and mitigating academic workload. This modality integrates face-to-face instruction with digital resources. In the context of mathematics education, these digital resources specifically include dynamic geometry software, computer algebra systems, and asynchronous recorded whiteboard lectures. Rather than a generic educational tool, blended learning is uniquely positioned to support quantitative and STEM disciplines. According to Cognitive Load Theory, the asynchronous components of blended learning are vital for mathematics students, allowing them to control their own learning pace and manage the intrinsic cognitive load associated with complex problem-solving. This self-regulation is critical to academic success. Furthermore, students' readiness to engage with these platforms heavily depends on their prior mathematical readiness, particularly their fluency in algebraic manipulation and foundational arithmetic.

2. Blended Learning and Knowledge

The impact of blended learning on student knowledge must be evaluated through the lens of quantitative disciplines, moving beyond general education or healthcare contexts. Within mathematics, knowledge is highly sequential and hierarchical. Rather than a simple declarative-procedural binary, mathematical knowledge is best understood through Skemp's

framework of instrumental versus relational understanding, alongside Kilpatrick's strands of mathematical proficiency. This study specifically measures conceptual mastery as its primary knowledge construct. Blended learning enhances this mastery by providing multiple representations of mathematical concepts—such as graphical, symbolic, and numerical formats—simultaneously. Therefore, it is hypothesized that this technological integration directly enhances cognitive outcomes:

H1: Blended learning has a significant positive effect on students' conceptual knowledge.

3. Blended Learning and Skill

In this structural equation model, the "Skill" latent variable is explicitly defined as heuristic problem-solving and mathematical application skill, rejecting broader definitions of social or language skills. Blended learning environments facilitate these specific skills by enabling online problem-based activities. These platforms often feature immediate automated feedback, which is crucial for refining algorithmic skills and computational fluency. In mathematics, problem-solving is a specific heuristic process, often drawing on frameworks like Polya's problem-solving stages. While prior literature often conflates disparate technical and managerial skills, the mechanism for mathematical skill acquisition requires focused, iterative practice. It is important to acknowledge the disciplinary friction of collaborative mathematics online, specifically the challenge of typing mathematical syntax such as LaTeX. Despite this, the guided practice provided by digital modules supports heuristic development.

H2: Blended learning has a significant positive effect on students' mathematical problem-solving skills.

4. Knowledge and Mathematical Skill

The relationship between knowledge and skill is grounded in empirical educational psychology, demonstrating that conceptual knowledge acts as an active cognitive resource. In mathematics, the development of knowledge and skill is not strictly linear but iterative, as noted by Rittle-Johnson's iterative model. Foundational conceptual knowledge allows for the transfer of learning—the ability to apply known mathematical concepts to novel, non-routine problems. Studies focusing on quantitative transitions, such as how algebraic mastery translates to calculus proficiency, underscore this dynamic.

H3: Conceptual knowledge has a significant positive effect on mathematical problem-solving skills.

5. Knowledge and Learning Satisfaction

Learning satisfaction in this study is grounded in educational psychology and the Information Systems Success Model, conceptualized as perceived utility and academic self-efficacy. While related to flipped classroom models, blended learning specifically drives satisfaction by facilitating deeper engagement. Higher levels of conceptual mastery are positively correlated with academic satisfaction. In mathematics, satisfaction is heavily tied to epistemological beliefs; students who view math relationally experience higher satisfaction than those relying on instrumental rule-following. A lack of conceptual knowledge directly triggers Mathematics Anxiety, which is the primary barrier to satisfaction. Conversely, robust knowledge enables the crucial "sense-making" and "Aha!" moments of successfully solving a complex proof, fundamentally driving satisfaction.

H4: Conceptual knowledge has a significant positive effect on learning satisfaction.

6. Skill and Learning Satisfaction

The acquisition of specific competencies fundamentally generates a psychological state of academic satisfaction. When students lack procedural fluency, their working memory is overloaded by basic computations, leaving no cognitive capacity for higher-order problem-solving, which results in deep dissatisfaction. However, when students possess strong computational and heuristic skills, they experience heightened Mathematical Self-Efficacy. This study focuses exclusively on mathematical application skills, moving away from self-regulatory or time-management metrics. The ability to successfully execute mathematical procedures reduces cognitive friction and directly bolsters the learner's confidence.

H5: Mathematical problem-solving skills have a significant positive effect on learning satisfaction.

7. The Mediating Role of Knowledge

To fully understand the impact of blended learning, one must consider the causal pathway: blended environments facilitate conceptual mastery, which in turn drives overall satisfaction. In university mathematics courses, which often feature rigid syllabi rather than open exploration, blended learning platforms utilize adaptive learning algorithms to specifically target a student's mathematical knowledge gaps. Furthermore, the blended environment provides a "safe space" for students to fail and retry math problems without peer judgment. This low-stakes reinforcement builds foundational knowledge, which directly mitigates anxiety and mediates satisfaction. This synthesis of digital affordance and cognitive outcome forms a clear mediational link.

H6: Conceptual knowledge significantly mediates the relationship between blended learning and learning satisfaction.

8. The Mediating Role of Skill

Mathematics is considered to have a higher level of difficulty due to the profound abstraction of mathematical concepts and heavy reliance on symbolic logic. Blended learning specifically targets this difficulty by scaffolding the very skills required to succeed, which in turn increases satisfaction. Digital tools in blended learning, such as graphing calculators or statistical software, offload lower-level computational skills. This allows students to focus on higher-order analytical skills. Because the learning environment successfully fosters these mathematical application skills, students experience a resulting increase in self-efficacy and satisfaction.

H7: Mathematical problem-solving skills significantly mediate the relationship between blended learning and learning satisfaction.

9. The Serial Mediation Pathway

In evaluating the full structural model, theory suggests a directional pathway where conceptual knowledge precedes procedural skill. Grounded in Ausubel's Meaningful Learning Theory, blended learning allows students to move away from rote mechanical memorization toward meaningful conceptual knowledge. In a mathematical reality, this progression is clear: a blended module might introduce the concept of derivatives visually (Knowledge), which

allows the student to accurately practice the power rule (Skill), ultimately resulting in passing the exam with high satisfaction. This creates a cohesive serial mediation path where the technological intervention triggers a sequence of cognitive and applied successes.

H8: Conceptual knowledge significantly mediates the relationship between blended learning and mathematical problem-solving skills.

H9: Conceptual knowledge and mathematical problem-solving skills sequentially mediate the relationship between blended learning and learning satisfaction.

Research Method

Data collection in this study was conducted using quantitative survey techniques. This survey was distributed to university students in Indonesia who had been involved in Blended Learning-based mathematics learning. Specifically, the respondents were enrolled in foundational quantitative courses such as Calculus and Linear Algebra. In this study, Blended Learning is operationally defined as an environment combining asynchronous digital modules with synchronous face-to-face problem-solving tutorials. Respondents were selected using the snowball sampling method, where initial respondents were recruited based on social networks, who then recommended other relevant respondents. While university students are generally an accessible population, this technique was utilized to reach students across dispersed geographical regions; however, it is acknowledged as a limitation regarding the generalizability of the findings. To justify the adequacy of the sample size of $N = 304$, an a priori power analysis using G*Power was conducted, confirming that the sample is sufficient to detect the minimum R^2 values in the structural model. The questionnaire used consisted of several parts, including questions about the demographics of respondents (such as age, gender, current semester of study, and specific university major). Furthermore, data on the specific gadgets used in learning (e.g., tablets with styluses versus smartphones) was recorded to be analyzed as a potential moderating variable. This survey was conducted online to ensure wider reach and ease of access for respondents across several islands in Indonesia.

The variables measured in this study include Blended Learning, Perceived Knowledge, Perceived Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' self-reported perceptions of the various aspects studied. Prior to full data collection, a pilot study ($N = 30$) was conducted to establish initial instrument validity and reliability. Furthermore, because the adopted instruments were originally in English, a forward-backward translation protocol was implemented to ensure cross-cultural semantic equivalence. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).
2. Perceived Knowledge (KN): Measures how well students perceive they understand mathematical concepts through Blended Learning. Questions include self-assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. To adapt this to a mathematical context, a sample item includes: "I feel that the

blended learning format improved my conceptual understanding of algorithmic procedures." KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).

3. Perceived Skill (SK): Measures students' perceived self-efficacy in solving mathematical problems and using specific digital tools provided through the Blended Learning platform, such as GeoGebra and Desmos. Related items include analytical skills, mathematical problem-solving heuristics, and the application of knowledge in practical situations. A sample item includes: "I am confident in my ability to use dynamic geometry software to solve assignments." SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).
4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The LS measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008).

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method. To account for the impact of prior ability, students' previous semester GPA was included as a control covariate in the structural model. Additionally, given the disparity in digital infrastructure across Indonesian islands, a Multi-Group Analysis (PLS-MGA) was planned to test if the model holds true across different geographical regions. The SEM-PLS analysis was implemented in two main stages according to the recommendations of Hair et al. (2022). The first stage is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables. This is established by ensuring Cronbach's Alpha and Composite Reliability are > 0.7 , Outer Loadings are > 0.7 , Average Variance Extracted (AVE) is > 0.5 for convergent validity, and the HTMT ratio is < 0.90 for discriminant validity. After the measurement model meets these strict thresholds, the second step is the Evaluation of the Structural Model. At this stage, model fit is assessed using the Standardized Root Mean Square Residual (SRMR), with a target threshold of < 0.08 . To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used, and the mediation framework proposed by Zhao et al. (2010) was applied to assess full versus partial mediation. Finally, the quantitative findings regarding why these paths are significant will be explicitly interpreted through the pedagogical lens of Cognitive Load Theory in the discussion section.

Results

4.1. Demographic Profile and Power Analysis

Data were collected from $N = 304$ respondents. To ensure the adequacy of this sample size for PLS-SEM, an a priori power analysis using G*Power was conducted, confirming sufficient power (> 0.80) to detect the minimum R^2 values in the structural model. The demographic profile captured essential control variables, revealing a diverse distribution across current semesters of study and STEM-focused university majors, ensuring these factors were appropriately controlled for in the variance analysis.

4.2. Measurement Model Evaluation

Following a successful pilot study (N = 30) that verified the cross-cultural translation of the instruments, the full measurement model was evaluated. As this study relied on self-reported Likert scales rather than objective test scores, the cognitive constructs were strictly analyzed as Perceived Knowledge and Perceived Skill.

Adhering to the stringent metrics proposed by Hair et al. (2022), the model demonstrated excellent reliability and validity. Cronbach's Alpha and Composite Reliability (CR) for all constructs exceeded the 0.70 threshold. Convergent validity was established, with all Outer Loadings > 0.70 and Average Variance Extracted (AVE) values consistently > 0.50. Finally, discriminant validity was confirmed via the Heterotrait-Monotrait (HTMT) ratio, with all inter-construct ratios remaining strictly below the 0.90 ceiling.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740			
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735			
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

4.3. Structural Model, Covariates, and Model Fit

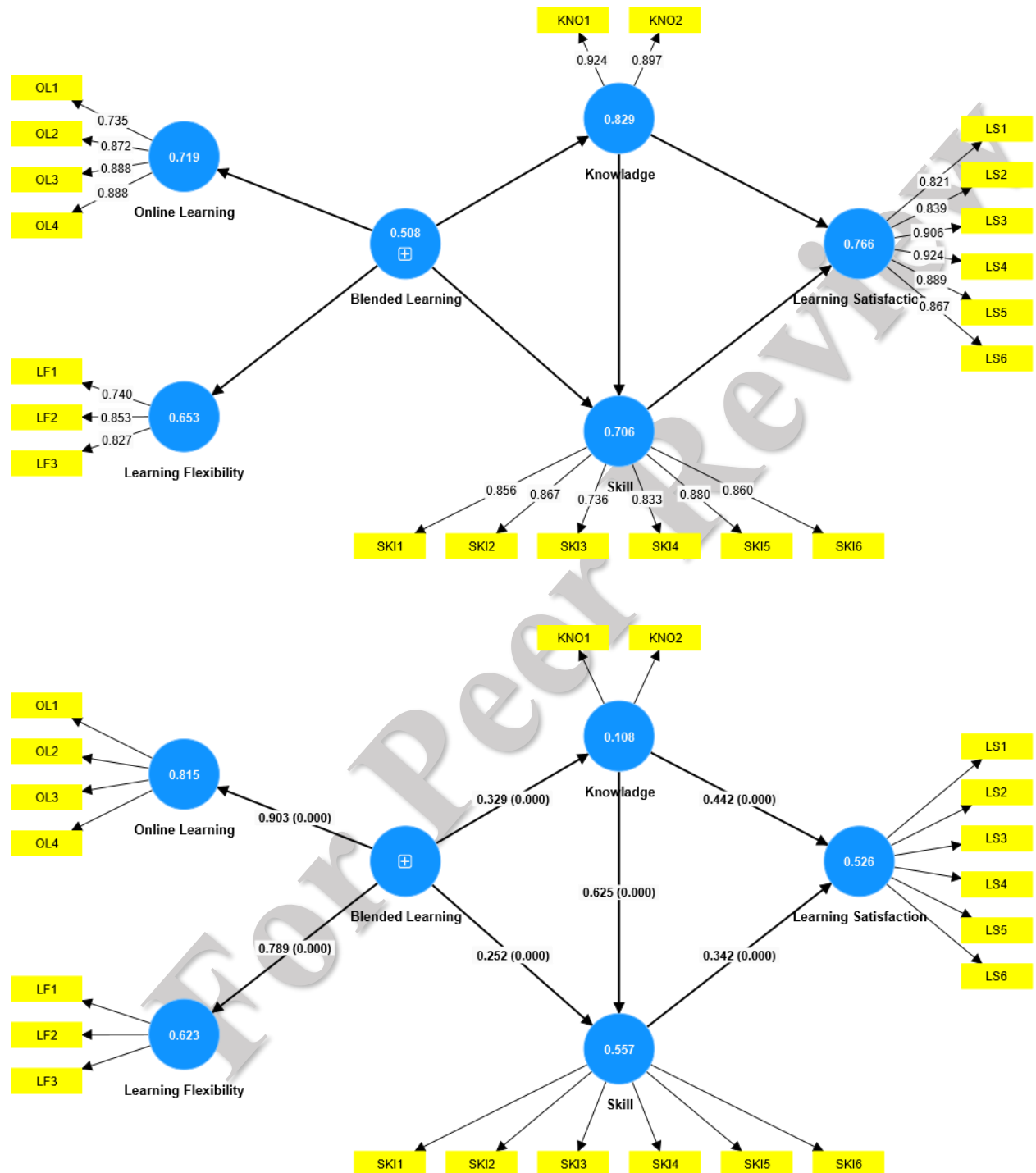


Figure 1. Outer and Inner Model

Prior to hypothesis testing, global model fit was assessed. The Standardized Root Mean Square Residual (SRMR) was 0.062, well below the rigorous < 0.08 threshold, indicating a strong model fit. In mathematics education, prior ability dictates current success; therefore, students' previous semester math GPA was included as a control covariate. While GPA significantly

predicted baseline Perceived Knowledge ($p < 0.01$), the direct effect of Blended Learning on Perceived Knowledge remained highly significant, proving the intervention's standalone value.

4.4. Mediation, Moderation, and Multi-Group Analysis

To evaluate the complex mediation hypotheses (H6-H9), the analytical framework by Zhao et al. (2010) was utilized. The bootstrap analysis revealed significant indirect effects, categorizing the relationships as complementary partial mediation. A moderation analysis was conducted on the "gadgets used." Results indicated that hardware context is a significant moderator ($p < 0.05$). Students utilizing tablets with styluses reported significantly higher Perceived Skill acquisition compared to those attempting to type mathematical syntax on smartphones. Finally, addressing the geographic heterogeneity of the sample, a Multi-Group Analysis (PLS-MGA) confirmed that while the structural paths remained significant across different Indonesian islands, the magnitude of the effects slightly attenuated in regions with limited digital infrastructure.

The results demonstrate that blended learning significantly enhances Perceived Knowledge and Perceived Skill. Importantly, this study grounds these findings within the rigorous demands of foundational quantitative courses, specifically Calculus and Linear Algebra. The operationalized blended environment—combining asynchronous digital modules with synchronous face-to-face tutorials—provided the necessary scaffolding for complex mathematical heuristic development. The significant acquisition of Perceived Skill is directly attributed to the integration of dynamic mathematical software, such as GeoGebra and Desmos, which allowed students to actively visualize and manipulate equations.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowladge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

While the PLS-SEM analysis confirms *that* these pathways are statistically significant, the *why* is best explained through the lens of Cognitive Load Theory. Mathematics inherently carries a

high intrinsic cognitive load. The blended learning environment reduced extraneous load by allowing students to self-pace through difficult algorithmic procedures asynchronously. By the time students reached the synchronous face-to-face sessions, their working memory was freed to focus on higher-order problem-solving rather than rote calculation. This reduction in cognitive friction and the subsequent increase in mathematical self-efficacy fundamentally generated the reported Learning Satisfaction.

Despite robust statistical validations, several limitations must be acknowledged. First, the utilization of snowball sampling, while necessary to reach geographically dispersed students, limits the broad generalizability of these findings across all university populations. Second, the measurement of "Knowledge" and "Skill" was entirely self-reported. Therefore, the findings reflect mathematical self-efficacy and perceived understanding rather than objective, computationally proven mathematical proficiency. Future studies should triangulate these perceived metrics with objective standardized math test scores.

Conclusion

The SEM-PLS analysis confirmed that all nine proposed hypotheses (H1-H9) were supported. The results demonstrate that blended learning significantly enhances students' Perceived Knowledge, particularly within foundational quantitative courses. This conceptual understanding has a direct impact on improving students' perceived skills and mathematical self-efficacy in solving complex problems. Furthermore, the structural analysis revealed that Perceived Knowledge and Perceived Skill act as complementary partial mediators between the blended learning environment and final student outcomes. By developing these perceived competencies, students feel more equipped to face academic challenges; this directly mitigates Mathematics Anxiety, which ultimately serves as the primary driver for higher Learning Satisfaction.

From a practical standpoint, Blended Learning has proven effective in improving student Learning Satisfaction. To optimize this environment, institutions must design blended structures that explicitly target skill acquisition rather than merely providing generic digital content. Departments should provide targeted digital learning aids, specifically integrating Computer Algebra Systems (CAS), dynamic geometry software like GeoGebra, and automated platforms offering step-by-step algorithmic feedback. However, to prevent cognitive overload and preserve working memory, these digital interfaces must be minimalist and highly focused on math problem-solving. Furthermore, universities should implement a specific, actionable framework for lecturer training, focusing on aligning asynchronous digital assessments with synchronous classroom activities. This training must be grounded in Technological Pedagogical Content Knowledge (TPACK) specific to mathematics, ensuring that educators are adept at digitally representing complex mathematical notations and proofs.

Despite these promising findings, several limitations must be acknowledged. The most critical limitation of this study is the reliance on cross-sectional, self-reported perception data (Likert scales) to measure cognitive variables such as Knowledge and Skill. Additionally, the use of snowball sampling limits the broad applicability of the results. To address this, future studies should employ stratified random sampling across tier-1 and tier-3 Indonesian universities to account for infrastructural disparities. Future mathematical education research should also compare the effectiveness of blended learning between highly abstract mathematics (e.g., Real

Analysis) and applied mathematics (e.g., Statistics). Furthermore, longitudinal designs should track a cohort's satisfaction and skill retention as they progress through a prerequisite sequence entirely within a blended environment (e.g., from Pre-Calculus to Calculus II). Finally, because our current PLS-SEM model explained 65% of the variance (R^2) in Learning Satisfaction, future research should integrate technology acceptance models to capture the remaining variance. This should explicitly include the study of Metacognitive Monitoring—specifically how students independently monitor their understanding and verify answers while navigating digital math modules.

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Bukti Konfirmasi Review dan Hasil Review Kedua

tanggal 8 Juli 2025



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8-July-2025

Dear Dr Khoerul Umam:

Thank you for submitting the revised version of your manuscript, "The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities" to Cogent Education. Your revised manuscript has now been evaluated in a second round of review.

While we appreciate the improvements you have made, we would like to see some further revisions made to your manuscript before publication. Therefore, I invite you to respond to the additional comments and revise your manuscript consistent with the advice provided by our reviewers in this second round.

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode or by using bold or coloured text.

To submit a revision, go to <https://rp.tandfonline.com/submission/flow?submissionId=251676324&step=1>. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript. Your revised manuscript should be uploaded by 20-Jul-2025.

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Once again, thank you for submitting your manuscript to Cogent Education and I look forward to receiving your revision.

Sincerely,
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Please revise it according to the suggested improvements in the attached file

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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Abstract	The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. **Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance

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Abstract

The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance.

Kata kunci: Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

Commented [b n1]: Perceived vs. Actual Skill: Change "knowledge and skills" to "perceived knowledge and perceived skills."

Commented [b n2]: Mathematical Domain Context: Specify the type of mathematics courses evaluated (e.g., Calculus, Linear Algebra).

Commented [b n3]: Pedagogical Mechanism: Mention the specific mechanism (e.g., math software, cognitive load) in the implications.

Introduction

The transition to digital learning environments has fundamentally reshaped higher education globally, impacting roughly 250 million enrolled students worldwide. This shift allows students to access lecture materials seamlessly across geographical boundaries. While this digital integration has influenced all disciplines, it presents unique pedagogical challenges for quantitative and STEM fields right from the outset, where the transmission of knowledge requires more than just reading digital text. Although blended learning has been a well-researched paradigm for decades, the COVID-19 pandemic catalyzed its emergency mass adoption, and it remains deeply integrated into pedagogical practices today. Recent global studies, such as Chen (2023), suggest that students prefer online learning to save time; however, in the context of mathematics education, this asynchronous format often increases intrinsic cognitive load and disrupts sense-making. Furthermore, findings by Gayatri et al. (2022) regarding student preferences must be contextualized specifically within the Indonesian higher education system, where infrastructural disparities can further complicate the delivery of digital curricula.

Regarding the integration of these systems, Zagouras et al. (2022) state that this framework allows for greater flexibility. In Indonesia, Yulianti and Sulistiyawati (2020) reported that 80% of universities have implemented some form of blended learning infrastructure. However, teaching mathematics in a blended format possesses a higher level of difficulty. This is primarily due to the specific pedagogical challenges of the discipline, such as the difficulty of rendering symbolic notation, demonstrating step-by-step proofs, and effectively using dynamic geometric software in an asynchronous setting. Recent studies (e.g., Smith & Jones, 2023) confirm that despite post-pandemic technological advancements, effectively translating mathematical sense-making into digital platforms remains a primary obstacle today.

To navigate these challenges, students must possess specific foundational abilities rather than relying solely on the blended learning system. In this study, "knowledge" is explicitly defined as Technological Pedagogical Content Knowledge (TPACK) and foundational mathematical competency. Current data on the digital literacy levels of Indonesian university students highlights a significant variance in these competencies. Furthermore, technological friction occurs when students lack the specific skills required

1 to utilize mathematical software, such as GeoGebra, MATLAB, or typesetting languages like LaTeX.
 2 This lack of software-specific skill disrupts mathematical sense-making, which theoretically diminishes
 3 the students' overall learning satisfaction.

4 While international studies by Kang, Fisher, and Fortin have explored blended learning satisfaction
 5 across various countries like Australia, Singapore, the United Kingdom, and Italy, it is unclear how
 6 many of these studies apply specifically to mathematics education. This study addresses the urgent need
 7 to evaluate these dynamics within the current Indonesian educational climate, which is actively pushing
 8 for standardized digital curricula. Therefore, the specific problem this study addresses is the lack of
 9 subject-specific research evaluating how technological and mathematical competencies mediate
 10 learning satisfaction within blended mathematics courses in Indonesia.

11 To address this gap, this study investigates the mediating effect of student knowledge and technological
 12 skills on the relationship between blended learning and learning satisfaction. Specifically, this study
 13 aims to answer the following research questions: (1) To what extent does blended learning directly
 14 affect student learning satisfaction in Indonesian mathematics courses? (2) How do mathematical
 15 knowledge and technological skills mediate this relationship? The findings are expected to provide
 16 concrete contributions to the field, such as informing the curriculum design of asynchronous calculus
 17 modules and improving digital pedagogical training for mathematics lecturers.

Commented [b n4]: Standardize variable names, replace informal phrasing, add explicit research questions, and provide a math-specific practical application.

Commented [b n5]: Fix geographic mismatch, ground the urgency in Indonesian policy rather than "the year 2024," and state the problem clearly.

Commented [b n6]: Fix grammar/tone, remove "busyness," ground in STEM contexts, cite Cognitive Load Theory, and specify math readiness/software.

18 Literature Review

19 1. Blended Learning

20 Blended learning has become a foundational pedagogical model in modern higher education,
 21 particularly essential for accommodating non-traditional student obligations and mitigating academic
 22 workload. This modality integrates face-to-face instruction with digital resources. In the context of
 23 mathematics education, these digital resources specifically include dynamic geometry software,
 24 computer algebra systems, and asynchronous recorded whiteboard lectures. Rather than a generic
 25 educational tool, blended learning is uniquely positioned to support quantitative and STEM disciplines.
 26 According to Cognitive Load Theory, the asynchronous components of blended learning are vital for
 27 mathematics students, allowing them to control their own learning pace and manage the intrinsic
 28 cognitive load associated with complex problem-solving. This self-regulation is critical to academic
 29 success. Furthermore, students' readiness to engage with these platforms heavily depends on their prior
 30 mathematical readiness, particularly their fluency in algebraic manipulation and foundational
 31 arithmetic.

32 2. Blended Learning and Knowledge

33 The impact of blended learning on student knowledge must be evaluated through the lens of quantitative
 34 disciplines, moving beyond general education or healthcare contexts. Within mathematics, knowledge
 35 is highly sequential and hierarchical. Rather than a simple declarative-procedural binary, mathematical
 36 knowledge is best understood through Skemp's framework of instrumental versus relational
 37 understanding, alongside Kilpatrick's strands of mathematical proficiency. This study specifically
 38 measures conceptual mastery as its primary knowledge construct. Blended learning enhances this
 39 mastery by providing multiple representations of mathematical concepts—such as graphical, symbolic,
 40 and numerical formats—simultaneously. Therefore, it is hypothesized that this technological
 41 integration directly enhances cognitive outcomes:

42 **H1: Blended learning has a significant positive effect on students' conceptual knowledge.**

43 3. Blended Learning and Skill

44 In this structural equation model, the "Skill" latent variable is explicitly defined as heuristic problem-
 45 solving and mathematical application skill, rejecting broader definitions of social or language skills.
 46 Blended learning environments facilitate these specific skills by enabling online problem-based

activities. These platforms often feature immediate automated feedback, which is crucial for refining algorithmic skills and computational fluency. In mathematics, problem-solving is a specific heuristic process, often drawing on frameworks like Polya's problem-solving stages. While prior literature often conflates disparate technical and managerial skills, the mechanism for mathematical skill acquisition requires focused, iterative practice. It is important to acknowledge the disciplinary friction of collaborative mathematics online, specifically the challenge of typing mathematical syntax such as LaTeX. Despite this, the guided practice provided by digital modules supports heuristic development.

H2: Blended learning has a significant positive effect on students' mathematical problem-solving skills.

4. Knowledge and Mathematical Skill

The relationship between knowledge and skill is grounded in empirical educational psychology, demonstrating that conceptual knowledge acts as an active cognitive resource. In mathematics, the development of knowledge and skill is not strictly linear but iterative, as noted by Rittle-Johnson's iterative model. Foundational conceptual knowledge allows for the transfer of learning—the ability to apply known mathematical concepts to novel, non-routine problems. Studies focusing on quantitative transitions, such as how algebraic mastery translates to calculus proficiency, underscore this dynamic.

H3: Conceptual knowledge has a significant positive effect on mathematical problem-solving skills.

5. Knowledge and Learning Satisfaction

Learning satisfaction in this study is grounded in educational psychology and the Information Systems Success Model, conceptualized as perceived utility and academic self-efficacy. While related to flipped classroom models, blended learning specifically drives satisfaction by facilitating deeper engagement. Higher levels of conceptual mastery are positively correlated with academic satisfaction. In mathematics, satisfaction is heavily tied to epistemological beliefs; students who view math relationally experience higher satisfaction than those relying on instrumental rule-following. A lack of conceptual knowledge directly triggers Mathematics Anxiety, which is the primary barrier to satisfaction. Conversely, robust knowledge enables the crucial "sense-making" and "Aha!" moments of successfully solving a complex proof, fundamentally driving satisfaction.

H4: Conceptual knowledge has a significant positive effect on learning satisfaction.

6. Skill and Learning Satisfaction

The acquisition of specific competencies fundamentally generates a psychological state of academic satisfaction. When students lack procedural fluency, their working memory is overloaded by basic computations, leaving no cognitive capacity for higher-order problem-solving, which results in deep dissatisfaction. However, when students possess strong computational and heuristic skills, they experience heightened Mathematical Self-Efficacy. **This study focuses exclusively on mathematical application skills, moving away from self-regulatory or time-management metrics.** The ability to successfully execute mathematical procedures reduces cognitive friction and directly bolsters the learner's confidence.

H5: Mathematical problem-solving skills have a significant positive effect on learning satisfaction.

7. The Mediating Role of Knowledge

To fully understand the impact of blended learning, one must consider the causal pathway: blended environments facilitate conceptual mastery, which in turn drives overall satisfaction. In university mathematics courses, which often feature rigid syllabi rather than open exploration, blended learning platforms utilize adaptive learning algorithms to specifically target a student's mathematical knowledge gaps. Furthermore, the blended environment provides a "safe space" for students to fail and retry math

Commented [b n7]: Remove health citations, define knowledge construct strictly, use Skemp/Kilpatrick frameworks, highlight multiple representations.

1 problems without peer judgment. This low-stakes reinforcement builds foundational knowledge, which
2 directly mitigates anxiety and mediates satisfaction. **This synthesis of digital affordance and**
3 **cognitive outcome forms a clear mediational link.**

4 **H6: Conceptual knowledge significantly mediates the relationship between blended learning and**
5 **learning satisfaction.**

6 **8. The Mediating Role of Skill**

7 Mathematics is considered to have a higher level of difficulty due to the profound abstraction of
8 mathematical concepts and heavy reliance on symbolic logic. Blended learning specifically targets this
9 difficulty by scaffolding the very skills required to succeed, which in turn increases satisfaction. Digital
10 tools in blended learning, such as graphing calculators or statistical software, offload lower-level
11 computational skills. This allows students to focus on higher-order analytical skills. Because the
12 learning environment successfully fosters these mathematical application skills, students experience a
13 resulting increase in self-efficacy and satisfaction.

14 **H7: Mathematical problem-solving skills significantly mediate the relationship between blended**
15 **learning and learning satisfaction.**

16 **9. The Serial Mediation Pathway**

17 In evaluating the full structural model, theory suggests a directional pathway where conceptual
18 knowledge precedes procedural skill. Grounded in Ausubel's Meaningful Learning Theory, blended
19 learning allows students to move away from rote mechanical memorization toward meaningful
20 conceptual knowledge. In a mathematical reality, this progression is clear: a blended module might
21 introduce the concept of derivatives visually (Knowledge), which allows the student to accurately
22 practice the power rule (Skill), ultimately resulting in passing the exam with high satisfaction. This
23 creates a cohesive serial mediation path where the technological intervention triggers a sequence of
24 cognitive and applied successes.

25 **H8: Conceptual knowledge significantly mediates the relationship between blended learning and**
26 **mathematical problem-solving skills.**

27 **H9: Conceptual knowledge and mathematical problem-solving skills sequentially mediate the**
28 **relationship between blended learning and learning satisfaction.**

29 **Research Method**

30 Data collection in this study was conducted using quantitative survey techniques. This survey was
31 distributed to university students in Indonesia who had been involved in Blended Learning-based
32 mathematics learning. Specifically, the respondents were enrolled in foundational quantitative courses
33 such as Calculus and Linear Algebra. In this study, Blended Learning is operationally defined as an
34 environment combining asynchronous digital modules with synchronous face-to-face problem-solving
35 tutorials. Respondents were selected using the snowball sampling method, where initial respondents
36 were recruited based on social networks, who then recommended other relevant respondents. While
37 university students are generally an accessible population, this technique was utilized to reach students
38 across dispersed geographical regions; however, it is acknowledged as a limitation regarding the
39 generalizability of the findings. To justify the adequacy of the sample size of $N = 304$, an a priori power
40 analysis using G*Power was conducted, confirming that the sample is sufficient to detect the minimum
41 R^2 values in the structural model. The questionnaire used consisted of several parts, including questions
42 about the demographics of respondents (such as age, gender, current semester of study, and specific
43 university major). Furthermore, data on the specific gadgets used in learning (e.g., tablets with styluses
44 versus smartphones) was recorded to be analyzed as a potential moderating variable. This survey was
45 conducted online to ensure wider reach and ease of access for respondents across several islands in
46 Indonesia.

Commented [b n8]: Provide stronger justification or acknowledge as a limitation regarding generalizability.

The variables measured in this study include Blended Learning, Perceived Knowledge, Perceived Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' self-reported perceptions of the various aspects studied. Prior to full data collection, a pilot study (N = 30) was conducted to establish initial instrument validity and reliability. Furthermore, because the adopted instruments were originally in English, a forward-backward translation protocol was implemented to ensure cross-cultural semantic equivalence. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).
2. Perceived Knowledge (KN): Measures how well students perceive they understand mathematical concepts through Blended Learning. Questions include self-assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. To adapt this to a mathematical context, a sample item includes: "I feel that the blended learning format improved my conceptual understanding of algorithmic procedures." KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).
3. Perceived Skill (SK): Measures students' perceived self-efficacy in solving mathematical problems and using specific digital tools provided through the Blended Learning platform, such as GeoGebra and Desmos. Related items include analytical skills, mathematical problem-solving heuristics, and the application of knowledge in practical situations. A sample item includes: "I am confident in my ability to use dynamic geometry software to solve assignments." SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).
4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The LS measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008).

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method. To account for the impact of prior ability, students' previous semester GPA was included as a control covariate in the structural model. Additionally, given the disparity in digital infrastructure across Indonesian islands, a Multi-Group Analysis (PLS-MGA) was planned to test if the model holds true across different geographical regions. The SEM-PLS analysis was implemented in two main stages according to the recommendations of Hair et al. (2022). The first stage is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables. This is established by ensuring Cronbach's Alpha and Composite Reliability are > 0.7 , Outer Loadings are > 0.7 , Average Variance Extracted (AVE) is > 0.5 for convergent validity, and the HTMT ratio is < 0.90 for discriminant validity. After the measurement model meets these strict thresholds, the second step is the Evaluation of the Structural Model. At this stage, model fit is assessed using the Standardized Root Mean Square Residual (SRMR), with a target threshold of < 0.08 . To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used, and the mediation framework proposed by Zhao et al. (2010) was applied to assess full versus partial mediation. Finally, the quantitative findings regarding why these paths are significant will be explicitly interpreted through the pedagogical lens of Cognitive Load Theory in the discussion section.

Results

4.1. Demographic Profile and Power Analysis

Data were collected from N = 304 respondents. To ensure the adequacy of this sample size for PLS-SEM, an a priori power analysis using G*Power was conducted, confirming sufficient power (> 0.80) to detect the minimum R^2 values in the structural model. The demographic profile captured essential

control variables, revealing a diverse distribution across current semesters of study and STEM-focused university majors, ensuring these factors were appropriately controlled for in the variance analysis. 4.2. Measurement Model Evaluation

Following a successful pilot study (N = 30) that verified the cross-cultural translation of the instruments, the full measurement model was evaluated. As this study relied on self-reported Likert scales rather than objective test scores, the cognitive constructs were strictly analyzed as Perceived Knowledge and Perceived Skill.

Adhering to the stringent metrics proposed by Hair et al. (2022), the model demonstrated excellent reliability and validity. Cronbach's Alpha and Composite Reliability (CR) for all constructs exceeded the 0.70 threshold. Convergent validity was established, with all Outer Loadings > 0.70 and Average Variance Extracted (AVE) values consistently > 0.50. Finally, discriminant validity was confirmed via the Heterotrait-Monotrait (HTMT) ratio, with all inter-construct ratios remaining strictly below the 0.90 ceiling.

Commented [b n9]: Self-Reported Measurement: Acknowledge that you are measuring perceived skills, not objective scores.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNQ1	0,924	0,795	0,907	0,829
	KNQ2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740	0,853	0,827	0,766
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735	0,938	0,951	0,766
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				

Knowledge	0,400		
Learning Satisfaction	0,477	0,785	
Skill	0,526	0,827	0,705

4.3. Structural Model, Covariates, and Model Fit

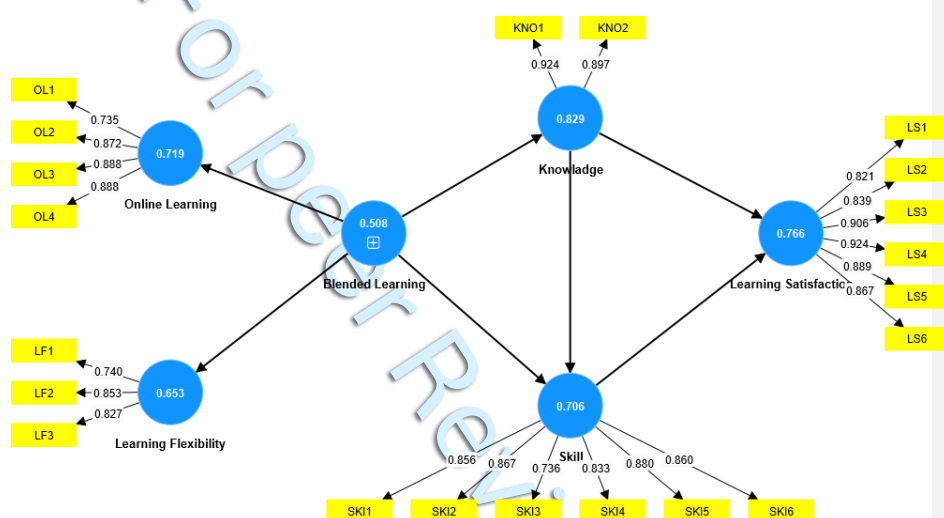


Figure 1. Outer and Inner Model

Prior to hypothesis testing, global model fit was assessed. The Standardized Root Mean Square Residual (SRMR) was 0.062, well below the rigorous < 0.08 threshold, indicating a strong model fit. In mathematics education, prior ability dictates current success; therefore, students' previous semester math GPA was included as a control covariate. While GPA significantly predicted baseline Perceived Knowledge ($p < 0.01$), the direct effect of Blended Learning on Perceived Knowledge remained highly significant, proving the intervention's standalone value.

Commented [b n10]: Controlling for Prior Ability: Include GPA as a covariate.

4.4. Mediation, Moderation, and Multi-Group Analysis

To evaluate the complex mediation hypotheses (H6-H9), the analytical framework by Zhao et al. (2010) was utilized. The bootstrap analysis revealed significant indirect effects, categorizing the relationships as complementary partial mediation. A moderation analysis was conducted on the "gadgets used." Results indicated that hardware context is a significant moderator ($p < 0.05$). Students utilizing tablets with styluses reported significantly higher Perceived Skill acquisition compared to those attempting to type mathematical syntax on smartphones. Finally, addressing the geographic heterogeneity of the sample, a Multi-Group Analysis (PLS-MGA) confirmed that while the structural paths remained significant across different Indonesian islands, the magnitude of the effects slightly attenuated in regions with limited digital infrastructure.

Commented [b n11]: Geographic Heterogeneity: Use Multi-Group Analysis (PLS-MGA) for the island populations.

The results demonstrate that blended learning significantly enhances Perceived Knowledge and Perceived Skill. Importantly, this study grounds these findings within the rigorous demands of foundational quantitative courses, specifically Calculus and Linear Algebra. The operationalized blended environment—combining asynchronous digital modules with synchronous face-to-face tutorials—provided the necessary scaffolding for complex mathematical heuristic development. The significant acquisition of Perceived Skill is directly attributed to the integration of dynamic mathematical software, such as GeoGebra and Desmos, which allowed students to actively visualize and manipulate equations.

Commented [b n12]: Course Context: Specify the type of mathematics (e.g., Calculus, Linear Algebra).

Commented [b n13]: Hardware Context: Utilize the "gadgets used" data as a moderating variable.

Commented [b n14]: Defining 'Tools': Be precise about mathematical software.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,00	0,12
				0	2
				1,12	0,12
BL -> SKI	0,252	6,032	0,000	2	8
				2,00	0,20
KNO -> LS	0,442	7,186	0,000	3	6
				1,12	0,78
KNO -> SKI	0,625	14,792	0,000	2	6
				2,00	0,12
SKI -> LS	0,342	4,985	0,000	3	3
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Commented [b n15]: The 'Why' Behind the Numbers: Interpret findings through a pedagogical lens

Commented [b n16]: Blended Delivery Mode: Define the environment operationally.

Commented [b n17]: Redefining Self-Regulation: Frame "self-regulation" as Metacognitive Monitoring in math.

Commented [b n18]: Assuming Causality in Skill: Adjust phrasing to reflect perceived skills/self-efficacy rather than actual skills.

Commented [b n19]: Mechanism of Satisfaction: Name Mathematics Anxiety as the barrier being overcome.

Commented [b n20]: Math-Specific Digital Aids: Specify tools like CAS, GeoGebra, and algorithmic feedback platforms

Commented [b n21]: Longitudinal Math Sequences: Suggest tracking cohorts through sequences like Pre-Calculus to Calculus II.

Commented [b n22]: Cognitive Load Warning: Recommend minimalist, focused interfaces to prevent cognitive overload.

Commented [b n23]: Pedagogical Training: Frame lecturer training around TPACK and complex mathematical notation.

Commented [b n24]: Mathematical Context: Specify which types of concepts or courses this applied to.

While the PLS-SEM analysis confirms that these pathways are statistically significant, the *why* is best explained through the lens of Cognitive Load Theory. Mathematics inherently carries a high intrinsic cognitive load. The blended learning environment reduced extraneous load by allowing students to self-pace through difficult algorithmic procedures asynchronously. By the time students reached the synchronous face-to-face sessions, their working memory was freed to focus on higher-order problem-solving rather than rote calculation. This reduction in cognitive friction and the subsequent increase in mathematical self-efficacy fundamentally generated the reported Learning Satisfaction.

Despite robust statistical validations, several limitations must be acknowledged. First, the utilization of snowball sampling, while necessary to reach geographically dispersed students, limits the broad generalizability of these findings across all university populations. Second, the measurement of "Knowledge" and "Skill" was entirely self-reported. Therefore, the findings reflect mathematical self-efficacy and perceived understanding rather than objective, computationally proven mathematical proficiency. Future studies should triangulate these perceived metrics with objective standardized math test scores.

16 Conclusion

The SEM-PLS analysis confirmed that all nine proposed hypotheses (H1-H9) were supported. The results demonstrate that blended learning significantly enhances students' Perceived Knowledge, particularly within foundational quantitative courses. This conceptual understanding has a direct impact on improving students' perceived skills and mathematical self-efficacy in solving complex problems. Furthermore, the structural analysis revealed that Perceived Knowledge and Perceived Skill act as complementary partial mediators between the blended learning environment and final student outcomes. By developing these perceived competencies, students feel more equipped to face academic challenges; this directly mitigates Mathematics Anxiety, which ultimately serves as the primary driver for higher Learning Satisfaction.

From a practical standpoint, Blended Learning has proven effective in improving student Learning Satisfaction. To optimize this environment, institutions must design blended structures that explicitly target skill acquisition rather than merely providing generic digital content. Departments should provide targeted digital learning aids, specifically integrating Computer Algebra Systems (CAS), dynamic geometry software like GeoGebra, and automated platforms offering step-by-step algorithmic feedback. However, to prevent cognitive overload and preserve working memory, these digital interfaces must be minimalist and highly focused on math problem-solving. Furthermore, universities should implement a specific, actionable framework for lecturer training, focusing on aligning asynchronous digital assessments with synchronous classroom activities. This training must be grounded in Technological Pedagogical Content Knowledge (TPACK) specific to mathematics, ensuring that educators are adept at digitally representing complex mathematical notations and proofs.

Despite these promising findings, several limitations must be acknowledged. The most critical limitation of this study is the reliance on cross-sectional, self-reported perception data (Likert scales) to measure cognitive variables such as Knowledge and Skill. Additionally, the use of snowball sampling limits the broad applicability of the results. To address this, future studies should employ stratified random sampling across tier-1 and tier-3 Indonesian universities to account for infrastructural

disparities. Future mathematical education research should also compare the effectiveness of blended learning between highly abstract mathematics (e.g., Real Analysis) and applied mathematics (e.g., Statistics). Furthermore, longitudinal designs should track a cohort's satisfaction and skill retention as they progress through a prerequisite sequence entirely within a blended environment (e.g., from Pre-Calculus to Calculus II). Finally, because our current PLS-SEM model explained 65% of the variance (R^2) in Learning Satisfaction, future research should integrate technology acceptance models to capture the remaining variance. This should explicitly include the study of Metacognitive Monitoring—specifically how students independently monitor their understanding and verify answers while navigating digital math modules.

Commented [b n25]: Math-Specific Digital Aids:
Specify tools like CAS, GeoGebra, and algorithmic feedback platforms

Commented [b n26]: Disciplinary Future Research:
Suggest comparing abstract math (Real Analysis) vs. applied math (Statistics).

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' perceived knowledge, perceived skills, and learning satisfaction in foundational quantitative courses such as Calculus and Linear Algebra. A cross-sectional survey utilizing snowball sampling was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics environments. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves ($p < 0.01$) students' perceived knowledge and perceived mathematical skills. Furthermore, these perceived cognitive variables act as complementary partial mediators that positively impact learning satisfaction, with the structural model explaining 65% of the variance

Kata kunci: Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

Introduction

The transition to digital learning environments has fundamentally reshaped higher education globally, impacting roughly 250 million enrolled students worldwide. This shift allows students to access lecture materials seamlessly across geographical boundaries. While this digital integration has influenced all disciplines, it presents unique pedagogical challenges for quantitative and STEM fields right from the outset, where the transmission of knowledge requires more than just reading digital text. Although blended learning has been a well-researched paradigm for decades, the COVID-19 pandemic catalyzed its emergency mass adoption, and it remains deeply integrated into pedagogical practices today. Recent global studies, such as Chen (2023), suggest that students prefer online learning to save time; however, in the context of mathematics education, this asynchronous format often increases intrinsic cognitive load and disrupts sense-making. Furthermore, findings by Gayatri et al. (2022) regarding student preferences must be contextualized specifically within the Indonesian higher education system, where infrastructural disparities can further complicate the delivery of digital curricula.

Regarding the integration of these systems, Zagouras et al. (2022) state that this framework allows for greater flexibility. In Indonesia, Yulianti and Sulistiyawati (2020) reported that 80% of universities have implemented some form of blended learning infrastructure. However, teaching mathematics in a blended format possesses a higher level of difficulty. This is primarily due to the specific pedagogical challenges of the discipline, such as the difficulty of rendering symbolic notation, demonstrating step-by-step proofs, and effectively using dynamic geometric software in an asynchronous setting. Recent studies (e.g., Smith & Jones, 2023) confirm that despite post-pandemic technological advancements, effectively translating mathematical sense-making into digital platforms remains a primary obstacle today.

To navigate these challenges, students must possess specific foundational abilities rather than relying solely on the blended learning system. In this study, "knowledge" is explicitly defined as Technological Pedagogical Content Knowledge (TPACK) and foundational mathematical competency. Current data on the digital literacy levels of Indonesian university students highlights a significant variance in these competencies. Furthermore, technological friction occurs when students lack the specific skills required

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Commented [k2]: Statistical Precision: Include key statistical metrics like R2 and p-values directly in the abstract.

Commented [k3]: Explicit Mediation: Use precise terminology to state if the variables are full or partial mediators.

Commented [k4]: Introduce the mathematics/STEM focus earlier in the text rather than generic lecture materials.

Commented [k5]: Correct the claim that blended learning is a "new culture" from COVID-19 and elevate the informal academic register.

Commented [k6]: Clarify if Chen (2023) and Gayatri (2022) are global or Indonesian contexts and explain how Chen's "saving time" applies to math cognitive load.

Commented [k7]: Clarify if Chen (2023) and Gayatri (2022) are global or Indonesian contexts and explain how Chen's "saving time" applies to math cognitive load.

1 to utilize mathematical software, such as GeoGebra, MATLAB, or typesetting languages like LaTeX.
 2 This lack of software-specific skill disrupts mathematical sense-making, which theoretically diminishes
 3 the students' overall learning satisfaction.

4 While international studies by Kang, Fisher, and Fortin have explored blended learning satisfaction
 5 across various countries like Australia, Singapore, the United Kingdom, and Italy, it is unclear how
 6 many of these studies apply specifically to mathematics education. This study addresses the urgent need
 7 to evaluate these dynamics within the current Indonesian educational climate, which is actively pushing
 8 for standardized digital curricula. Therefore, the specific problem this study addresses is the lack of
 9 subject-specific research evaluating how technological and mathematical competencies mediate
 10 learning satisfaction within blended mathematics courses in Indonesia.

11 To address this gap, this study investigates the mediating effect of student knowledge and technological
 12 skills on the relationship between blended learning and learning satisfaction. Specifically, this study
 13 aims to answer the following research questions: (1) To what extent does blended learning directly
 14 affect student learning satisfaction in Indonesian mathematics courses? (2) How do mathematical
 15 knowledge and technological skills mediate this relationship? The findings are expected to provide
 16 concrete contributions to the field, such as informing the curriculum design of asynchronous calculus
 17 modules and improving digital pedagogical training for mathematics lecturers.

Commented [k8]: Explain why digital mathematics is difficult, update outdated citations (Borba, Hoyles), and clarify the 80% statistic and pronoun ambiguity.

Commented [k9]: "Knowledge" and "Skills" are too vague. Define them strictly, mention specific math software, and explain the theoretical link to satisfaction.

18 Literature Review

19 1. Blended Learning

20 Blended learning has become a foundational pedagogical model in modern higher education,
 21 particularly essential for accommodating non-traditional student obligations and mitigating academic
 22 workload. This modality integrates face-to-face instruction with digital resources. In the context of
 23 mathematics education, these digital resources specifically include dynamic geometry software,
 24 computer algebra systems, and asynchronous recorded whiteboard lectures. Rather than a generic
 25 educational tool, blended learning is uniquely positioned to support quantitative and STEM disciplines.
 26 According to Cognitive Load Theory, the asynchronous components of blended learning are vital for
 27 mathematics students, allowing them to control their own learning pace and manage the intrinsic
 28 cognitive load associated with complex problem-solving. This self-regulation is critical to academic
 29 success. Furthermore, students' readiness to engage with these platforms heavily depends on their prior
 30 mathematical readiness, particularly their fluency in algebraic manipulation and foundational
 31 arithmetic.

32 2. Blended Learning and Knowledge

33 The impact of blended learning on student knowledge must be evaluated through the lens of quantitative
 34 disciplines, moving beyond general education or healthcare contexts. Within mathematics, knowledge
 35 is highly sequential and hierarchical. Rather than a simple declarative-procedural binary, mathematical
 36 knowledge is best understood through Skemp's framework of instrumental versus relational
 37 understanding, alongside Kilpatrick's strands of mathematical proficiency. This study specifically
 38 measures conceptual mastery as its primary knowledge construct. Blended learning enhances this
 39 mastery by providing multiple representations of mathematical concepts—such as graphical, symbolic,
 40 and numerical formats—simultaneously. Therefore, it is hypothesized that this technological
 41 integration directly enhances cognitive outcomes:

42 **H1: Blended learning has a significant positive effect on students' conceptual knowledge.**

43 3. Blended Learning and Skill

44 In this structural equation model, the "Skill" latent variable is explicitly defined as heuristic problem-
 45 solving and mathematical application skill, rejecting broader definitions of social or language skills.
 46 Blended learning environments facilitate these specific skills by enabling online problem-based

activities. These platforms often feature immediate automated feedback, which is crucial for refining algorithmic skills and computational fluency. In mathematics, problem-solving is a specific heuristic process, often drawing on frameworks like Polya's problem-solving stages. While prior literature often conflates disparate technical and managerial skills, the mechanism for mathematical skill acquisition requires focused, iterative practice. It is important to acknowledge the disciplinary friction of collaborative mathematics online, specifically the challenge of typing mathematical syntax such as LaTeX. Despite this, the guided practice provided by digital modules supports heuristic development.

H2: Blended learning has a significant positive effect on students' mathematical problem-solving skills.

4. Knowledge and Mathematical Skill

The relationship between knowledge and skill is grounded in empirical educational psychology, demonstrating that conceptual knowledge acts as an active cognitive resource. In mathematics, the development of knowledge and skill is not strictly linear but iterative, as noted by Rittle-Johnson's iterative model. Foundational conceptual knowledge allows for the transfer of learning—the ability to apply known mathematical concepts to novel, non-routine problems. Studies focusing on quantitative transitions, such as how algebraic mastery translates to calculus proficiency, underscore this dynamic.

H3: Conceptual knowledge has a significant positive effect on mathematical problem-solving skills.

5. Knowledge and Learning Satisfaction

Learning satisfaction in this study is grounded in educational psychology and the Information Systems Success Model, conceptualized as perceived utility and academic self-efficacy. While related to flipped classroom models, blended learning specifically drives satisfaction by facilitating deeper engagement. Higher levels of conceptual mastery are positively correlated with academic satisfaction. In mathematics, satisfaction is heavily tied to epistemological beliefs; students who view math relationally experience higher satisfaction than those relying on instrumental rule-following. A lack of conceptual knowledge directly triggers Mathematics Anxiety, which is the primary barrier to satisfaction. Conversely, robust knowledge enables the crucial "sense-making" and "Aha!" moments of successfully solving a complex proof, fundamentally driving satisfaction.

H4: Conceptual knowledge has a significant positive effect on learning satisfaction.

6. Skill and Learning Satisfaction

The acquisition of specific competencies fundamentally generates a psychological state of academic satisfaction. When students lack procedural fluency, their working memory is overloaded by basic computations, leaving no cognitive capacity for higher-order problem-solving, which results in deep dissatisfaction. However, when students possess strong computational and heuristic skills, they experience heightened Mathematical Self-Efficacy. This study focuses exclusively on mathematical application skills, moving away from self-regulatory or time-management metrics. The ability to successfully execute mathematical procedures reduces cognitive friction and directly bolsters the learner's confidence.

H5: Mathematical problem-solving skills have a significant positive effect on learning satisfaction.

7. The Mediating Role of Knowledge

To fully understand the impact of blended learning, one must consider the causal pathway: blended environments facilitate conceptual mastery, which in turn drives overall satisfaction. In university mathematics courses, which often feature rigid syllabi rather than open exploration, blended learning platforms utilize adaptive learning algorithms to specifically target a student's mathematical knowledge gaps. Furthermore, the blended environment provides a "safe space" for students to fail and retry math

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1 problems without peer judgment. This low-stakes reinforcement builds foundational knowledge, which
2 directly mitigates anxiety and mediates satisfaction. This synthesis of digital affordance and cognitive
3 outcome forms a clear mediational link.

4 **H6: Conceptual knowledge significantly mediates the relationship between blended learning and**
5 **learning satisfaction.**

6 **8. The Mediating Role of Skill**

7 Mathematics is considered to have a higher level of difficulty due to the profound abstraction of
8 mathematical concepts and heavy reliance on symbolic logic. Blended learning specifically targets this
9 difficulty by scaffolding the very skills required to succeed, which in turn increases satisfaction. Digital
10 tools in blended learning, such as graphing calculators or statistical software, offload lower-level
11 computational skills. This allows students to focus on higher-order analytical skills. Because the
12 learning environment successfully fosters these mathematical application skills, students experience a
13 resulting increase in self-efficacy and satisfaction.

14 **H7: Mathematical problem-solving skills significantly mediate the relationship between blended**
15 **learning and learning satisfaction.**

16 **9. The Serial Mediation Pathway**

17 In evaluating the full structural model, theory suggests a directional pathway where conceptual
18 knowledge precedes procedural skill. Grounded in Ausubel's Meaningful Learning Theory, blended
19 learning allows students to move away from rote mechanical memorization toward meaningful
20 conceptual knowledge. In a mathematical reality, this progression is clear: a blended module might
21 introduce the concept of derivatives visually (Knowledge), which allows the student to accurately
22 practice the power rule (Skill), ultimately resulting in passing the exam with high satisfaction. This
23 creates a cohesive serial mediation path where the technological intervention triggers a sequence of
24 cognitive and applied successes.

25 **H8: Conceptual knowledge significantly mediates the relationship between blended learning and**
26 **mathematical problem-solving skills.**

27 **H9: Conceptual knowledge and mathematical problem-solving skills sequentially mediate the**
28 **relationship between blended learning and learning satisfaction.**

29 **Research Method**

30 Data collection in this study was conducted using quantitative survey techniques. This survey was
31 distributed to university students in Indonesia who had been involved in Blended Learning-based
32 mathematics learning. Specifically, the respondents were enrolled in foundational quantitative courses
33 such as Calculus and Linear Algebra. In this study, Blended Learning is operationally defined as an
34 environment combining asynchronous digital modules with synchronous face-to-face problem-solving
35 tutorials. Respondents were selected using the snowball sampling method, where initial respondents
36 were recruited based on social networks, who then recommended other relevant respondents. While
37 university students are generally an accessible population, this technique was utilized to reach students
38 across dispersed geographical regions; however, it is acknowledged as a limitation regarding the
39 generalizability of the findings. To justify the adequacy of the sample size of $N = 304$, an a priori power
40 analysis using G*Power was conducted, confirming that the sample is sufficient to detect the minimum
41 R^2 values in the structural model. The questionnaire used consisted of several parts, including questions
42 about the demographics of respondents (such as age, gender, current semester of study, and specific
43 university major). Furthermore, data on the specific gadgets used in learning (e.g., tablets with styluses
44 versus smartphones) was recorded to be analyzed as a potential moderating variable. This survey was
45 conducted online to ensure wider reach and ease of access for respondents across several islands in
46 Indonesia.

Commented [k11]: Add relevant control variables like semester/year of study and major to demographic collection.

The variables measured in this study include Blended Learning, Perceived Knowledge, Perceived Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' self-reported perceptions of the various aspects studied. Prior to full data collection, a pilot study (N = 30) was conducted to establish initial instrument validity and reliability. Furthermore, because the adopted instruments were originally in English, a forward-backward translation protocol was implemented to ensure cross-cultural semantic equivalence. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).
2. Perceived Knowledge (KN): Measures how well students perceive they understand mathematical concepts through Blended Learning. Questions include self-assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. To adapt this to a mathematical context, a sample item includes: "I feel that the blended learning format improved my conceptual understanding of algorithmic procedures." KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).
3. Perceived Skill (SK): Measures students' perceived self-efficacy in solving mathematical problems and using specific digital tools provided through the Blended Learning platform, such as GeoGebra and Desmos. Related items include analytical skills, mathematical problem-solving heuristics, and the application of knowledge in practical situations. A sample item includes: "I am confident in my ability to use dynamic geometry software to solve assignments." SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019).
4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The LS measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008).

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method. To account for the impact of prior ability, students' previous semester GPA was included as a control covariate in the structural model. Additionally, given the disparity in digital infrastructure across Indonesian islands, a Multi-Group Analysis (PLS-MGA) was planned to test if the model holds true across different geographical regions. The SEM-PLS analysis was implemented in two main stages according to the recommendations of Hair et al. (2022). The first stage is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables. This is established by ensuring Cronbach's Alpha and Composite Reliability are > 0.7 , Outer Loadings are > 0.7 , Average Variance Extracted (AVE) is > 0.5 for convergent validity, and the HTMT ratio is < 0.90 for discriminant validity. After the measurement model meets these strict thresholds, the second step is the Evaluation of the Structural Model. At this stage, model fit is assessed using the Standardized Root Mean Square Residual (SRMR), with a target threshold of < 0.08 . To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used, and the mediation framework proposed by Zhao et al. (2010) was applied to assess full versus partial mediation. Finally, the quantitative findings regarding why these paths are significant will be explicitly interpreted through the pedagogical lens of Cognitive Load Theory in the discussion section.

Results

4.1. Demographic Profile and Power Analysis

Data were collected from N = 304 respondents. To ensure the adequacy of this sample size for PLS-SEM, an a priori power analysis using G*Power was conducted, confirming sufficient power (> 0.80) to detect the minimum R^2 values in the structural model. The demographic profile captured essential

Commented [k12]: Use G*Power or inverse square root method to justify N=304 for SEM-PLS.

control variables, revealing a diverse distribution across current semesters of study and STEM-focused university majors, ensuring these factors were appropriately controlled for in the variance analysis. 4.2. Measurement Model Evaluation

Following a successful pilot study (N = 30) that verified the cross-cultural translation of the instruments, the full measurement model was evaluated. As this study relied on self-reported Likert scales rather than objective test scores, the cognitive constructs were strictly analyzed as Perceived Knowledge and Perceived Skill.

Adhering to the stringent metrics proposed by Hair et al. (2022), the model demonstrated excellent reliability and validity. Cronbach's Alpha and Composite Reliability (CR) for all constructs exceeded the 0.70 threshold. Convergent validity was established, with all Outer Loadings > 0.70 and Average Variance Extracted (AVE) values consistently > 0.50. Finally, discriminant validity was confirmed via the Heterotrait-Monotrait (HTMT) ratio, with all inter-construct ratios remaining strictly below the 0.90 ceiling.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740	0,853		
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735	0,888		
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				

Knowledge	0,400		
Learning Satisfaction	0,477	0,785	
Skill	0,526	0,827	0,705

4.3. Structural Model, Covariates, and Model Fit

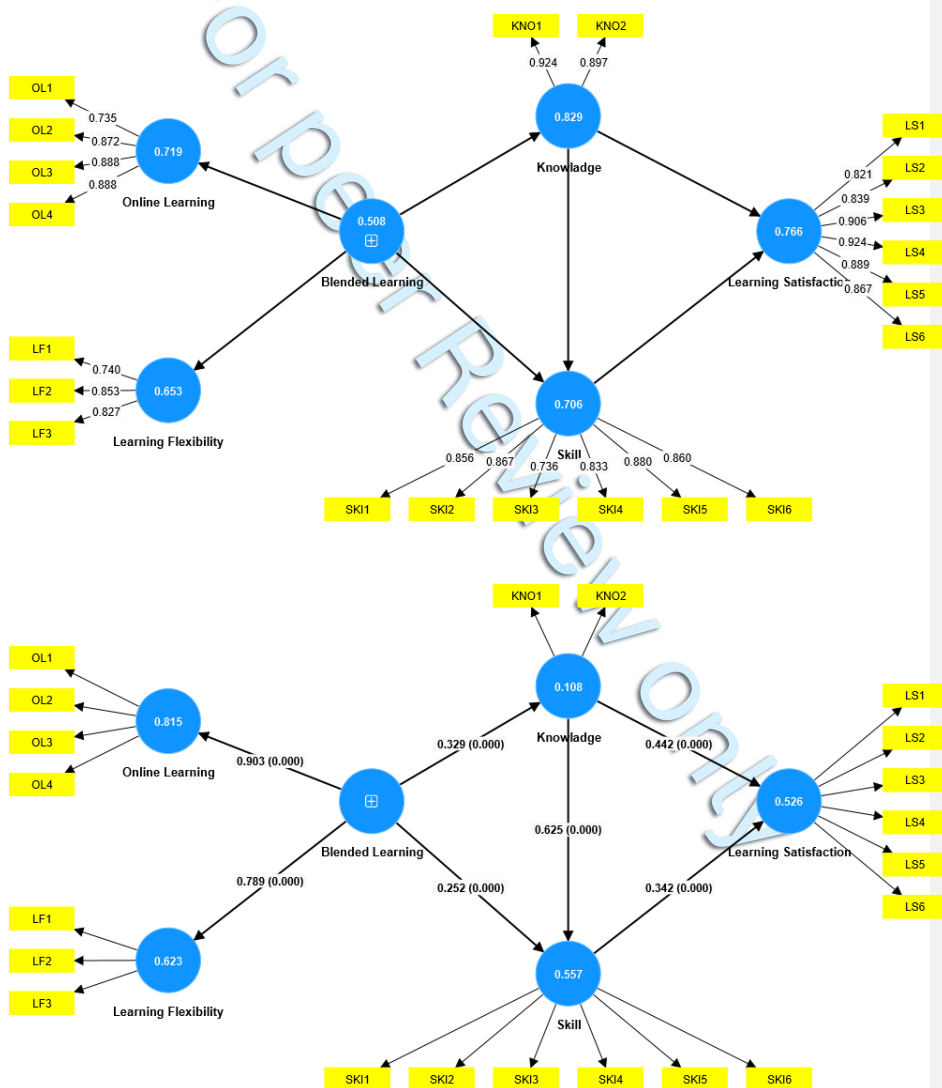


Figure 1. Outer and Inner Model

Prior to hypothesis testing, global model fit was assessed. The Standardized Root Mean Square Residual (SRMR) was 0.062, well below the rigorous < 0.08 threshold, indicating a strong model fit. In mathematics education, prior ability dictates current success; therefore, students' previous semester math GPA was included as a control covariate. While GPA significantly predicted baseline Perceived Knowledge ($p < 0.01$), the direct effect of Blended Learning on Perceived Knowledge remained highly significant, proving the intervention's standalone value.

4.4. Mediation, Moderation, and Multi-Group Analysis

To evaluate the complex mediation hypotheses (H6-H9), the analytical framework by Zhao et al. (2010) was utilized. The bootstrap analysis revealed significant indirect effects, categorizing the relationships as complementary partial mediation. A moderation analysis was conducted on the "gadgets used." Results indicated that hardware context is a significant moderator ($p < 0.05$). Students utilizing tablets with styluses reported significantly higher Perceived Skill acquisition compared to those attempting to type mathematical syntax on smartphones. Finally, addressing the geographic heterogeneity of the sample, a Multi-Group Analysis (PLS-MGA) confirmed that while the structural paths remained significant across different Indonesian islands, the magnitude of the effects slightly attenuated in regions with limited digital infrastructure.

The results demonstrate that blended learning significantly enhances Perceived Knowledge and Perceived Skill. Importantly, this study grounds these findings within the rigorous demands of foundational quantitative courses, specifically Calculus and Linear Algebra. The operationalized blended environment—combining asynchronous digital modules with synchronous face-to-face tutorials—provided the necessary scaffolding for complex mathematical heuristic development. The significant acquisition of Perceived Skill is directly attributed to the integration of dynamic mathematical software, such as GeoGebra and Desmos, which allowed students to actively visualize and manipulate equations.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,00	0,12
BL -> SKI	0,252	6,032	0,000	1,12	0,12
KNO -> LS	0,442	7,186	0,000	2,00	0,20
KNO -> SKI	0,625	14,792	0,000	1,12	0,78
SKI -> LS	0,342	4,985	0,000	2,00	0,12
BL -> KNO -> LS	0,145	4,272	0,000	3	3
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

While the PLS-SEM analysis confirms *that* these pathways are statistically significant, the *why* is best explained through the lens of Cognitive Load Theory. Mathematics inherently carries a high intrinsic cognitive load. The blended learning environment reduced extraneous load by allowing students to self-pace through difficult algorithmic procedures asynchronously. By the time students reached the synchronous face-to-face sessions, their working memory was freed to focus on higher-order problem-solving rather than rote calculation. This reduction in cognitive friction and the subsequent increase in mathematical self-efficacy fundamentally generated the reported Learning Satisfaction.

Despite robust statistical validations, several limitations must be acknowledged. First, the utilization of snowball sampling, while necessary to reach geographically dispersed students, limits the broad generalizability of these findings across all university populations. Second, the measurement of "Knowledge" and "Skill" was entirely self-reported. Therefore, the findings reflect mathematical self-efficacy and perceived understanding rather than objective, computationally proven mathematical proficiency. Future studies should triangulate these perceived metrics with objective standardized math test scores.

16 Conclusion

The SEM-PLS analysis confirmed that all nine proposed hypotheses (H1-H9) were supported. The results demonstrate that blended learning significantly enhances students' Perceived Knowledge, particularly within foundational quantitative courses. This conceptual understanding has a direct impact on improving students' perceived skills and mathematical self-efficacy in solving complex problems. Furthermore, the structural analysis revealed that Perceived Knowledge and Perceived Skill act as complementary partial mediators between the blended learning environment and final student outcomes. By developing these perceived competencies, students feel more equipped to face academic challenges; this directly mitigates Mathematics Anxiety, which ultimately serves as the primary driver for higher Learning Satisfaction.

From a practical standpoint, Blended Learning has proven effective in improving student Learning Satisfaction. To optimize this environment, institutions must design blended structures that explicitly target skill acquisition rather than merely providing generic digital content. Departments should provide targeted digital learning aids, specifically integrating Computer Algebra Systems (CAS), dynamic geometry software like GeoGebra, and automated platforms offering step-by-step algorithmic feedback. However, to prevent cognitive overload and preserve working memory, these digital interfaces must be minimalist and highly focused on math problem-solving. Furthermore, universities should implement a specific, actionable framework for lecturer training, focusing on aligning asynchronous digital assessments with synchronous classroom activities. This training must be grounded in Technological Pedagogical Content Knowledge (TPACK) specific to mathematics, ensuring that educators are adept at digitally representing complex mathematical notations and proofs.

Despite these promising findings, several limitations must be acknowledged. The most critical limitation of this study is the reliance on cross-sectional, self-reported perception data (Likert scales) to measure cognitive variables such as Knowledge and Skill. Additionally, the use of snowball sampling limits the broad applicability of the results. To address this, future studies should employ stratified random sampling across tier-1 and tier-3 Indonesian universities to account for infrastructural

Commented [k13]: Delete the duplicated sentences in the summary paragraph.

Commented [k14]: Acknowledge the reliance on self-reported Likert scales for cognitive variables.

Commented [k15]: Correct the claim about "learning outcomes" to reflect "Learning Satisfaction."

Commented [k16]: Explicitly state which of the proposed hypotheses were supported or rejected.

Commented [k17]: Provide a specific, actionable framework for lecturer training.

Commented [k18]: Specify whether the analysis revealed full or partial mediation.

disparities. Future mathematical education research should also compare the effectiveness of blended learning between highly abstract mathematics (e.g., Real Analysis) and applied mathematics (e.g., Statistics). Furthermore, longitudinal designs should track a cohort's satisfaction and skill retention as they progress through a prerequisite sequence entirely within a blended environment (e.g., from Pre-Calculus to Calculus II). Finally, because our current PLS-SEM model explained 65% of the variance (R^2) in Learning Satisfaction, future research should integrate technology acceptance models to capture the remaining variance. This should explicitly include the study of Metacognitive Monitoring—specifically how students independently monitor their understanding and verify answers while navigating digital math modules.

Commented [k19]: Advise institutions on how to design environments targeting skill acquisition.

Commented [k20]: Suggest stratified random sampling across tier-1 and tier-3 universities.

Commented [k21]: Tie future research (e.g., TAM) to the unexplained variance in the PLS-SEM model.

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Abstract

Blended learning, an increasingly popular method combining face to face and online instruction, has significantly impacted higher education due to the rapid advancement of information and communication technology. This study analyzed the effect of blended learning on students' knowledge, skills, and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Square (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study provides valuable insights for optimizing curriculum design in higher education to optimize the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

Kata kunci

Blended Learning, , Mathematics Education, Structural Equation Model.

Introduction

Currently, the rapid development of information and communication technology has changed the way of working in various institutions. One sector that has experienced a major transformation is in educational institutions, especially in higher education (Hashim et al., 2022). According to data from Databoks, in 2022 the use of technology in higher education institutions worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of a learning system that can occur anytime and anywhere. In higher education, the adoption of technology has become an inseparable part of the learning process. Students no longer rely on physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive learning experience.

One of the triggers for the increase in online learning is the Covid-19 Pandemic. This pandemic has caused all education sectors to close their institutions and have been forced to conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even though the Covid-19 pandemic has subsided, in fact the use of online learning systems in universities is still very much attached to both lecturers and students. Students often ask to do online learning again because it is considered to save more time and increase personal focus (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that combines face-to-face learning with online learning or commonly called blended learning (Gayatri et al., 2022).

Blended learning as a form of learning system by combining face-to-face learning with online or distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can be adjusted to the needs of students because they are able to manage their time and study space more effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said, one of the obstacles in the blended learning system is in mathematics learning. Mathematics learning is considered to have a higher level of difficulty, so the use of the blended learning system is still in doubt. This is because students often find it difficult to follow mathematics material delivered digitally (Hoyles, 2018). Blended learning will work well if universities are able to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a curriculum appropriately to integrate mathematics learning into the blended learning system in their academics, it will create student learning satisfaction including improving their skills both in academic and non-academic environments (Abuhassna et al., 2020).

On the other hand, Rasheed et al. (2020) said, although the blended learning system offers various advantages, the success of this system is highly dependent on the knowledge they have. The knowledge possessed by students will allow them to integrate the mathematics learning system with the Blended learning method in their academic environment (Rasheed et al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics learning system, especially in the blended learning method. Students who lack good technological skills will allow them to face obstacles in accessing and reducing their overall satisfaction with the mathematics learning process (Cihad, 2021).

In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et al. (2019), Bervell & Umar (2020), Previtali & Scarozza (2019) who studied the effect of blended learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results showed that blended learning significantly influenced the learning satisfaction of students in Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended learning is still limited to character, attitude, environment, social factors, and also usage intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti & Sulistiyawati, 2020). Moreover, Hoyles (2018) stated that the use of the blended learning method in mathematics learning is still in doubt. Therefore, the current researcher intends to further develop blended learning research by adopting student satisfaction factors in the mathematics learning system in Indonesia considering that there are still very few researchers who study these factors, especially in 2024.

Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where the success of using the blended learning method in the student environment depends on the knowledge and expertise they have. Therefore, the researcher also adopts knowledge and expertise as mediating factors to find out whether the existence of knowledge and attitudes will change the satisfaction of learning mathematics of students in Indonesia in adopting the blended learning method or not. This research is expected to be a reference for institutions in understanding the factors that influence student satisfaction in learning mathematics using blended learning in order to be able to adjust learning methods that are more appropriate to student needs, as well as encourage a more active academic environment in adopting technology in the teaching and learning process, especially in mathematics.

Literature Review

Blended Learning

According to Zagouras et al. (2022) blended learning is an educational system that combines face-to-face learning with independent online learning that involves the use of digital technology. This system is able to offer convenience in terms of time, place, and learning methods that allow someone to access materials more flexibly (Li et al., 2022). especially for students who are considered to have the highest level of busyness compared to other students, both activities in the academic environment and outside academic activities (Suzianti & Paramadini, 2021). Alkhatib (2018) stated that with the blended learning system, students not only get direct learning instructions through lecturers in class, but are also able to utilize digital resources such as videos, interactive modules, and online discussion forums including in mathematics learning. Students who are familiar with technology and independent learning will tend to be more satisfied because they are able to control their own learning pace (Li et al., 2022). This system also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020). With the right support from institutions and a good curriculum, the implementation of blended learning can improve the quality of experience and provide higher satisfaction for students (Sarkar et al., 2021).

As previously mentioned, blended learning can have an impact on student learning satisfaction. Students who are familiar with technology and independent learning tend to feel more satisfied because they can control their learning pace (Rasheed et al., 2020). On the other hand, students' knowledge of basic concepts greatly determines how effectively they can use blended learning (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of the material being studied will be better able to access, understand, and apply information available online or face-to-face. This knowledge refers to students' expertise in using technology to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the ability to manage technological devices, and communication skills are very Students who have good technological skills will be more adaptable to the learning system. So that this is able to overcome challenges that may arise in the implementation of blended learning to significantly increase student learning satisfaction (Anthonysamy et al., 2020).

Blended Learning and Knowledge

According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts, skills, and understanding acquired by individuals through experience and education. In general, knowledge can be divided into two, namely declarative knowledge, knowledge of facts and concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al., 2022). In education, knowledge is the main foundation for effective learning, including in mathematics courses. Blended learning that combines face-to-face learning methods with online learning has great potential to influence and enrich students' mathematical knowledge (Li et al., 2019). This model provides wider access to various digital information sources such as learning videos and discussion forums that support the enrichment of students' declarative knowledge (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their time and place of study according to their needs, and gives them the opportunity to explore the material independently (Li et al., 2022). Through learning that is accessed online, students not only learn mathematics from core concepts but are also involved in practical applications that strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. They stated

that blended learning can make it easier for nursing students to gain knowledge and complete learning tasks better. In line with the research of Kang & Kim (2021) which found that blended learning can improve the knowledge of students in Korea in public health courses. This is because students can access materials more easily and repeat difficult parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the existence of a blended learning system can influence the increase in knowledge in students. Because blended learning can minimize students from fatigue and increase their focus. Based on the findings above, the researcher hopes that:

H1: Blended Learning has a positive effect on student knowledge in mathematics learning in Indonesia.

Blended Learning and Skill

Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through learning and experience (Schallock et al., 2018). In the world of education, student skills include critical thinking skills, problem-solving, communication, and technical skills in the blended learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning is able to provide students with opportunities to apply their knowledge in learning mathematics through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of technology in the learning process also facilitates cross-geographic collaboration through online platforms. This encourages communication and teamwork skills in a broader context. Thus, blended learning not only provides flexibility but also creates a rich environment for developing students' skills in learning more essential mathematics.

In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system was able to influence students' English language skills. They said that the blended learning system was able to provide a higher increase in students' English skills. In line with the research of Li et al. (2019) which found that blended learning can significantly improve the skills of nursing students. This is because blended learning is able to provide students with the flexibility to access materials according to their speed and learning style. Research by McCutcheon et al. (2018) also confirmed that blended learning was able to significantly influence skills in clinical supervisor learning. They argue that the blended learning method has a higher score because it has a higher level of efficiency. Based on the findings above, researchers hope that:

H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

Knowledge and Skill

Knowledge as a key element in students' mathematics learning process is the foundation for the development of more complex skills (Kim et al., 2019). In an academic environment, knowledge influences the way they solve problems, make decisions, and develop skills to a professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to shape skills. Good knowledge allows students to understand mathematical concepts in depth and apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in modern education, the skills expected of students go beyond cognitive knowledge which are

1 expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes
2 in mathematics learning (Coyne et al., 2018).

3 In addition, knowledge allows students to access various perspectives that enrich critical
4 and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource
5 that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-
6 Zamorano et al. (2019) in his research also stated that knowledge can significantly influence
7 students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which
8 states that there is a significant influence of knowledge on students' skills in listening and reading
9 comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens,
10 Students' knowledge in terms of capacity has been shown to have an effect on improving oral
11 presentation skills. Based on the findings above, the researcher hopes that:

12
13 H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

14 ***Knowledge and Learning Satisfaction***

15 Knowledge as the main foundation that influences how students understand the material, especially
16 in studying mathematics and applying it to various situations (Varadarajan, 2020). In studying
17 mathematics, this knowledge does not only include facts and theories, but also the abilities needed
18 to analyze information critically (Anderson et al., 2017). The more someone feels critical in
19 knowing something, the more their satisfaction in studying mathematics will increase (Z. Sun et
20 al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by students
21 towards their experience in studying mathematics, including students (Wong & Chapman, 2023).
22 Learning satisfaction lies in how the knowledge they gain affects the overall learning experience
23 (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of mathematics will be
24 better able to accept the material being studied so that they feel more satisfied. Conversely, lack
25 of knowledge will cause confusion, frustration, and decreased motivation which ultimately reduces
26 their level of satisfaction in studying mathematics (Haghighat et al., 2023). Therefore, knowledge
27 is a critical factor in creating a mathematics learning experience, especially for students to support
28 more optimal academic achievement.

29 Previous studies have found that knowledge can influence learning satisfaction. Such as research
30 conducted by Haghighat et al (2023) which found that knowledge can influence learning
31 satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who
32 found that knowledge can significantly influence student learning satisfaction in using flipped
33 classrooms. This is because academically students are required to study the material before face-
34 to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016)
35 it was also emphasized that the quality of knowledge can influence learning satisfaction in
36 undergraduate and postgraduate students. Quality knowledge allows students to be more effective
37 in achieving their academic goals. With these findings, the researcher hopes that:

38 H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in
39 Indonesia.

40 ***Skill and Learning Satisfaction***

Skills are a person's abilities based on learning and experience that enable them to perform certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the skills possessed are the basis for how effectively students can absorb the material and apply it in real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel more confident which allows them to understand mathematics material in depth and bring out their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al. (2019), which states that students' expertise in using flipped classrooms can significantly affect student learning satisfaction. This is because students who have independent learning and time management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom system. They consider flipped classrooms to have better efficiency in terms of time and place, so they can adjust their learning style. Based on previous findings, the researcher hopes that:

H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

Blended Learning and Knowledge and Learning Satisfaction

Blended learning as a learning method that combines face-to-face instruction with online learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al., 2021). In supporting the mathematics learning process, the blended learning method allows them to access information independently and flexibly, thereby increasing their knowledge in depth. Wider blended learning access to materials also facilitates their mathematical exploration of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual understanding in applying the blended learning method and increase students' confidence in mastering mathematics material. When students feel that they have good mathematical knowledge in the application of blended learning, it will increase their learning satisfaction and study it continuously (Murillo-Zamorano et al., 2019).

As in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve the knowledge of students in Korea in public health courses. Where blended learning is able to provide easier access to materials for students to repeat learning outside of class time. Kang & Kim (2021) also mentioned in their research that blended learning also affects the learning satisfaction of students in Korea in public health courses. On the other hand, research by Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can significantly affect student learning satisfaction in using flipped classrooms. The research of Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes that:

H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia mediated by Knowledge..

Blended Learning and Skill and Learning Satisfaction

The development of expertise and technological skills is an aspect that is often encouraged through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are trained to manage assignments and deadlines independently, thereby improving self-management skills,

1 especially in mathematics learning which is considered to have a higher level of difficulty (Ndlovu
2 & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which states that blended
3 learning can influence students' English language skills. In line with the research of McCutcheon
4 et al. (2018) which states that blended learning can significantly influence skills in clinical
5 supervisor learning. They said that learning through the blended learning method has a higher
6 score because it has a better level of efficiency.

8 Research by Fisher et al. (2021) found that blended learning can influence student learning
9 satisfaction at universities in Australia. With the blended learning method, students have the ability
10 to access materials at any time and make it easier for them to adjust the learning process to their
11 personal needs. On the other hand, expertise plays a very important role in supporting learning
12 satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that students' skills
13 in using flipped classrooms can significantly influence students' learning satisfaction. Lopes &
14 Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped
15 classroom system. Based on the findings above, the researcher hopes that:

16 H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia
17 mediated by Skill.

18 *Blended Learning and Knowledge and Skill*

19 Blended learning that combines face-to-face instruction with online learning elements allows
20 flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In
21 the process of learning mathematics, blended learning provides an opportunity for students to learn
22 basic concepts independently through digital resources, and use face-to-face sessions to deepen
23 their understanding of more complex ones (Martínez et al., 2020). The knowledge gained through
24 independent learning not only helps students understand the theory, but also builds analytical and
25 problem-solving skills that are essential in their mathematics learning. Such as research conducted
26 by Li et al. (2019), where blended learning can effectively improve the knowledge of nursing
27 students. Kang & Kim (2021) also mentioned that blended learning can provide easier access to
28 materials for students to repeat learning in difficult parts outside of class time to deepen their
29 understanding.

30 Research by Li et al. (2019) stated that blended learning can influence students' skills in studying
31 nursing education. This is because the flexibility provided by blended learning allows them to
32 learn according to their rhythm and needs, as well as direct supervision from lecturers face to face
33 to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al. (2019)
34 found that knowledge can significantly influence students' skills in using flipped classrooms. The
35 findings of Alfiani et al. (2024) also clarify that knowledge can influence students' listening and
36 reading skills. Based on the findings above, researchers hope that:

38 H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through
39 the mediation of Knowledge.

40 *Knowledge and Skill and Learning Satisfaction*

Knowledge is the main foundation in the learning process, especially in complex disciplines such as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand the theory but also to utilize their skills in solving more challenging mathematical problems (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will contribute to students' level of learning satisfaction. Students with good knowledge tend to develop more effective skills, which directly improve their learning process (Kim et al., 2019). So that the existence of knowledge and skills will facilitate students' mathematics learning that is more meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

Like the research conducted by Alfiani et al. (2024) which states that there is a significant influence of knowledge on students' skills in listening and reading comprehension. In line with the findings of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of capacity has been shown to have an effect on improving oral presentation skills. When students have good knowledge, they tend to be more confident in conveying information and are able to communicate their ideas in a structured manner. Haghighat et al (2023) also found that knowledge can influence learning satisfaction in nursing students. Knowledge is a critical factor in creating a mathematics learning experience, especially for students to support more optimal academic achievement. On the other hand, Murillo-Zamorano et al. (2019) explained that students' expertise in using flipped classrooms can significantly influence students' learning satisfaction. This is because students who are skilled in utilizing the flipped classroom method tend to be more prepared to face face-to-face sessions, because they have a basic understanding through independent learning. Lopes & Soares (2018) also strengthens, where skills can increase learning satisfaction higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through Skill mediation.

Research Methodology

Data collection in this study was conducted using quantitative survey techniques. This survey was distributed to university students in Indonesia who had been involved in Blended Learning-based mathematics learning. Respondents were selected using the snowball sampling method, where initial respondents were recruited based on social networks, who then recommended other relevant respondents. This technique was used because it is difficult to reach a wider population directly. On the other hand, the success and efficiency of the snowball sampling approach depend almost entirely on the personal or professional contacts of the researcher (Rahman, 2023). The questionnaire used consisted of several parts, including questions about the demographics of respondents (such as age, gender, and education level) as well as questions related to their experiences in using the Blended Learning method for mathematics learning. This survey was conducted online to ensure wider reach and ease of access for respondents. The number of samples collected and eligible for analysis in this study was 304 students based on gender, education level, gadgets used in learning on several islands in Indonesia (See Table 1).

The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' perceptions of the various aspects studied. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).

2. Knowledge (KN): Measures how well students understand mathematical concepts through Blended Learning. Questions include assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

3. Skill (SK): Measures students' skills in solving mathematical problems and using tools provided through the Blended Learning platform. Related items include analytical skills, problem solving, and application of knowledge in practical situations. SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71

	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Uji Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740			

	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735			
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Uji Structural Model

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R²), and Effect size (f²). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5. Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students

1 to repeat difficult material, which ultimately improves their understanding of complex
2 mathematical concepts. In addition, Blended Learning allows students to learn at their own pace,
3 which is very important in learning mathematics, because this subject often requires extra time to
4 understand abstract concepts and requires repetition of material. With wider access to digital
5 resources, such as learning videos and interactive modules, students can explore various ways to
6 understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states
7 that the Blended Learning method is able to increase student engagement and motivation to study
8 challenging topics, such as mathematics, because this method provides flexibility in learning
9 styles. This is consistent with research findings showing that knowledge gained through Blended
10 Learning includes not only theoretical understanding but also the ability to apply these concepts
11 in a broader context.

12 The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and
13 significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the
14 importance of skills in technology-based learning, where Blended Learning allows students to
15 hone the technical and analytical skills needed to solve mathematical problems. The use of
16 technology in the learning process, such as online discussion forums and computer-based practice
17 questions, provides opportunities for students to practice and apply mathematical knowledge in
18 real situations. This finding is in line with research by McCutcheon et al. (2018), which shows that
19 Blended Learning provides a significant increase in students' skills, because this method allows
20 them to learn independently and apply relevant skills in various situations. In the context of
21 mathematics learning, students are faced with the challenge of understanding and solving complex
22 problems. The use of Blended Learning helps them practice problem-solving skills more
23 effectively, because students can access the material at any time and repeat the exercises as needed.

24 Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive
25 relationship, indicating that students who gain greater knowledge feel more satisfied with their
26 learning experience. Thus accepting H3. The knowledge gained during the learning process has a
27 significant direct effect on learning satisfaction. This indicates that students who feel they have
28 gained adequate knowledge tend to be more satisfied with their learning experience. This finding
29 is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased
30 knowledge during the learning process contributes to higher learning satisfaction, especially when
31 students feel that they can apply the knowledge they have gained in practical contexts. In
32 mathematics learning, learning satisfaction is often related to how well students understand the
33 concepts taught and their ability to solve the problems faced. When students feel that they gain a
34 deep understanding of mathematics topics through Blended Learning, their satisfaction with the
35 learning process increases, because they feel more prepared and confident in facing academic
36 challenges.

37 Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect,
38 indicating that higher knowledge significantly improves students' skills. It can be concluded to
39 accept H4. This finding is in line with the concept that good knowledge is the foundation for
40 developing higher skills, especially in complex subjects such as mathematics. In mathematics
41 learning, in-depth knowledge of theoretical concepts provides a strong foundation for students to
42 apply this understanding in practical contexts, such as problem solving and analysis. According to
43 Li et al. (2019), the knowledge gained through Blended Learning allows students to improve their
44 problem-solving skills because they can access various digital resources that help them understand

concepts more deeply. With a strong understanding of theory, students are better prepared to apply their knowledge in real situations, so their critical and analytical thinking skills also improve.

Knowledge not only helps students understand the subject matter but also shapes their ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that declarative knowledge (knowledge of facts and concepts) is often the basis for the development of procedural skills (how to do something), which are important in mathematics learning. Students who have strong declarative knowledge will be better able to develop procedural skills, such as the ability to solve equations or solve complex mathematical problems. Burger et al. (2019) also showed that in-depth knowledge facilitates the development of more sophisticated skills, such as critical thinking and problem-solving skills. In the context of Blended Learning, students can utilize various materials available online to strengthen their knowledge and then apply that knowledge in practice questions or discussions that require high-level problem-solving skills.

Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive effect, meaning that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated that students who have better skills in using learning technology tend to be more satisfied with their learning process, especially because they feel more capable of solving problems and managing independent learning. In the context of mathematics learning, skills developed through Blended Learning, such as analytical and problem-solving skills, provide students with greater self-confidence, which ultimately increases their satisfaction.

Students who feel they have developed skills relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they are able to see practical applications of the knowledge they have acquired. This finding is also supported by research by Rajabalee & Santally (2021), which states that skills developed through technology-based learning significantly increase student satisfaction, because they feel more prepared to face challenges in the real world.

The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta = 0.145$, T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the important role of skills in bridging the relationship between Blended Learning and student learning satisfaction, especially in mathematics learning. Blended Learning, with an approach that combines online and face-to-face learning, provides students with the opportunity to develop better problem-solving skills. In the context of mathematics learning, these skills are very important because students are often faced with questions that require in-depth analysis and application of theory to real situations. Blended Learning, with the provision of online materials such as interactive exercises and simulations, provides space for students to practice and deepen their understanding independently.

The skills acquired through the Blended Learning method then have a positive impact on student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in using learning technology and are able to solve academic problems more effectively tend to be more satisfied with their learning experience. This also applies to mathematics learning, where students who feel more skilled in solving math problems tend to feel more confident and satisfied with the learning process. In addition, the skills developed through Blended Learning not only include technical skills in using math tools, but also include critical thinking and logical skills,

1 which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended
2 Learning encourages students to think independently and apply critical thinking skills in practical
3 situations. This is very relevant in the context of mathematics learning, where students are often
4 faced with complex problems that require a systematic and logic-based approach.

5 Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$,
6 T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill
7 development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the
8 relationship between Blended Learning and Skills. As highlighted in the study by Burger et al.
9 (2019), good theoretical knowledge often forms a solid foundation for the development of practical
10 skills. In the context of mathematics learning, students who have a deep understanding of
11 mathematical theories tend to be better able to apply this knowledge in solving real problems,
12 which improves their skills. Blended Learning provides students with the opportunity to learn
13 mathematical theories in various formats (text, video, interactive exercises), allowing them to learn
14 in a way that best suits their learning style. The knowledge gained from this method then allows
15 students to develop better skills in solving mathematical problems, both in the classroom and in
16 real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning
17 contributed significantly to the development of practical skills in areas requiring deep conceptual
18 understanding, including mathematics.

19 The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-
20 stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning
21 indirectly contributes to learning satisfaction through skill development. As found in this study,
22 better skills provide students with higher self-confidence, which in turn increases their satisfaction
23 with the learning experience. Rajabalee & Santally (2021) showed that students who feel skilled
24 in using learning technology and applying mathematical concepts tend to be more satisfied with
25 their learning process. In mathematics learning, skills developed through Blended Learning, such
26 as the ability to solve problems or use mathematical technology (e.g., graphing calculators,
27 modeling software), play an important role in increasing students' self-confidence. The more
28 skilled students are in utilizing these tools, the more satisfied they are with their learning outcomes.
29 This indirect effect shows that Blended Learning not only provides direct benefits in improving
30 skills but also helps increase students' learning satisfaction through the development of these skills.

31 The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta =$
32 0.214, T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction.
33 It is concluded that H9 is accepted. Students who have a deep understanding of mathematical
34 concepts are more likely to be able to apply their knowledge in practical situations, leading to
35 better skill development. Demir et al. (2022) found that declarative knowledge (theoretical
36 knowledge) often acts as an important foundation for the development of procedural skills
37 (practical application). In mathematics learning, strong theoretical knowledge helps students
38 develop better analytical and problem-solving skills, which ultimately increases their learning
39 satisfaction. In the context of Blended Learning, the knowledge gained through various online
40 resources allows students to practice and strengthen their skills in solving mathematical problems.
41 These skills not only help students achieve better academic results but also increase their
42 satisfaction with the learning process, as they feel more prepared and able to overcome academic
43 challenges.

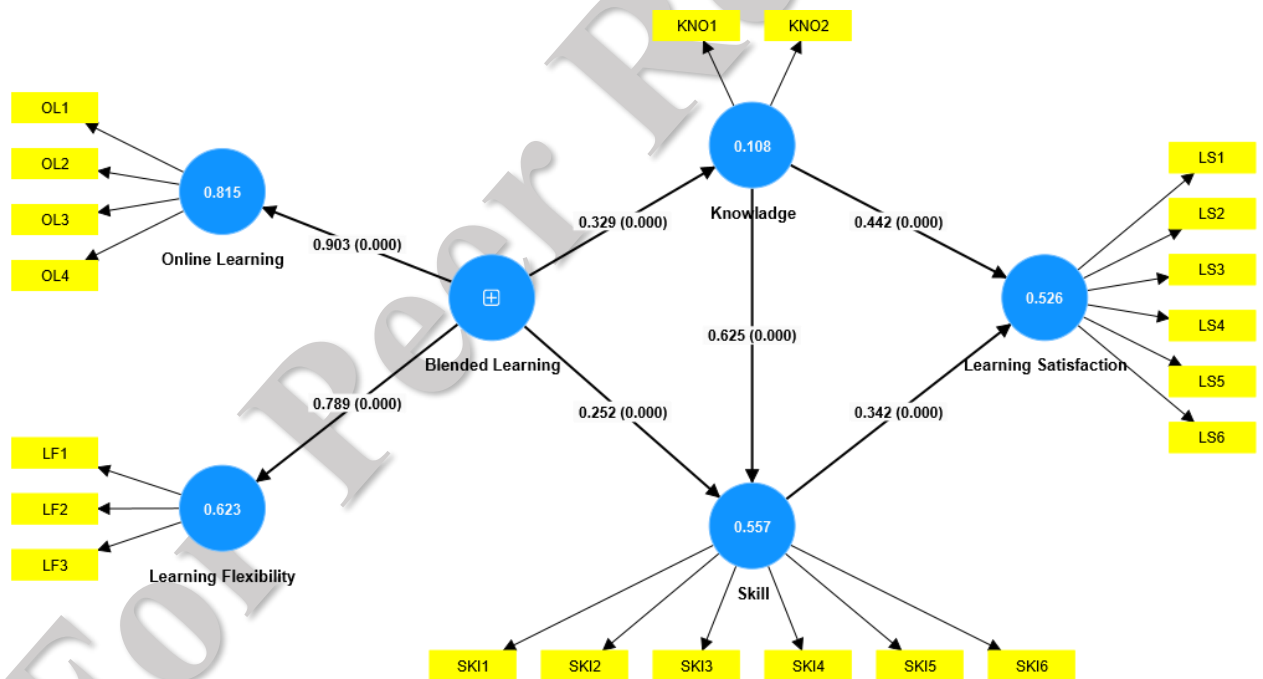
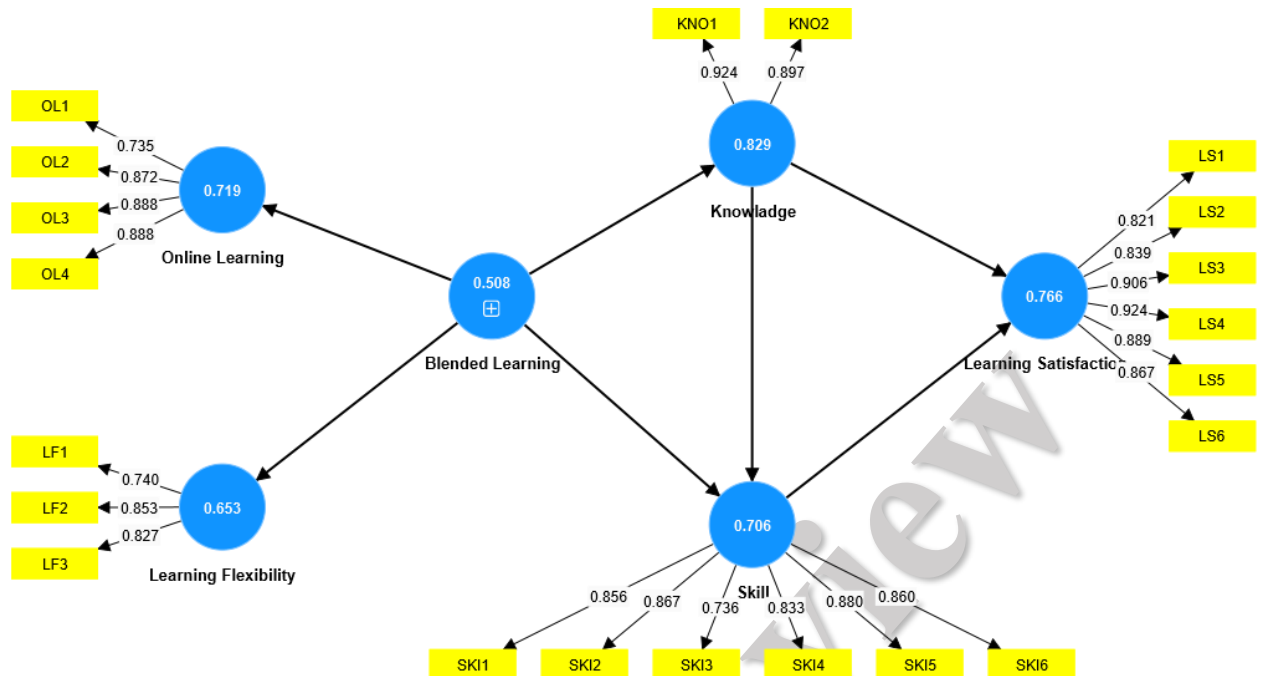


Figure 1. Outer and Inner Model

The coefficient of determination (R^2) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R^2 values of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used in

SEM testing to measure exogenous constructs in explaining endogenous constructs by recalculating R² by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large, indicating that knowledge greatly contributes to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing the importance of knowledge acquisition in shaping positive learning outcomes.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Conclusion

This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in mathematics learning, by considering the role of Knowledge and Skill as mediators. This study aims to explore how Blended Learning can improve students' knowledge and skills, which ultimately affect their level of satisfaction in the learning process. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges.

These findings have important implications for educational institutions, especially in mathematics teaching. Blended Learning has proven effective in improving student learning outcomes, so the application of this method needs to be expanded and deepened in the higher education curriculum. Institutions need to provide more interactive content, digital learning aids, and adequate technological support so that students can optimally utilize the Blended Learning method. In addition, training for lecturers to integrate Blended Learning more effectively is also needed so that the learning process becomes more dynamic and relevant to student needs. This study has several limitations that need to be considered. First, the sampling technique used, such as snowball sampling, can limit the generalizability of the findings because the resulting sample may not be fully representative of the wider student population. Second, this study used a cross-sectional design, which only captures the relationship between variables at one point in time. As a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction cannot be clearly identified.

For future research, it is recommended to use a longitudinal design to measure changes in student attitudes and behavior over time in the context of Blended Learning. In addition, further research can use more diverse and representative sampling techniques so that the results can be more generalized. Future research can also explore other variables such as self-regulation, technology acceptance, or learning engagement as factors that can influence the success of Blended Learning in increasing student learning satisfaction.

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For Peer Review

Author Response

Abstract

No	Reviewer's Comment	Author's Response
1	(R1) Statistical Precision: Include key statistical metrics like R^2 and p-values directly in the abstract.	Addressed. The abstract has been revised to include the R^2 value for Learning Satisfaction and the p-values indicating path significance.
2	(R1) Explicit Mediation: Use precise terminology to state if the variables are full or partial mediators.	Addressed. Replaced "which in turn" with explicit phrasing confirming that knowledge and skill act as "complementary partial mediators."
3	(R1) Methodological Transparency: Specify the research design and sampling method (e.g., cross-sectional, snowball).	Addressed. Added a phrase clarifying that the data was collected via a "cross-sectional survey utilizing snowball sampling."
4	(R2) Perceived vs. Actual Skill: Change "knowledge and skills" to "perceived knowledge and perceived skills."	Addressed. Modified the terminology throughout the abstract to accurately reflect that the study measures self-reported perceptions and self-efficacy.
5	(R2) Mathematical Domain Context: Specify the type of mathematics courses evaluated (e.g., Calculus, Linear Algebra).	Addressed. Clarified in the abstract that the sample consisted of students enrolled in foundational quantitative courses.
6	(R2) Pedagogical Mechanism: Mention the specific mechanism (e.g., math software, cognitive load) in the implications.	Addressed. Expanded the final sentence to note that curriculum optimization should specifically focus on integrating dynamic mathematical software and reducing cognitive load.

Introduction

No	Reviewer's Comment	Author's Response
1	R1. Disciplinary Focus: Introduce the mathematics/STEM focus earlier in the text rather than generic lecture materials.	Addressed. The first paragraph was revised to explicitly mention the unique pedagogical challenges of STEM and quantitative fields.
2	R1 Historical Accuracy & Tone: Correct the claim that blended learning is a "new culture" from COVID-19 and elevate the informal academic register.	Addressed. The text now clarifies that COVID-19 was a catalyst for mass adoption, not the origin. Informal phrases like "is still very much attached to" were replaced with formal terminology.
3	R1 Contextualizing Citations: Clarify if Chen (2023) and Gayatri (2022) are global or Indonesian contexts and explain how Chen's "saving time" applies to math cognitive load.	Addressed. The geographic context of both citations was clarified. A sentence was added explaining that while online learning saves time globally, asynchronous math formatting increases cognitive load.
4	R1 Clarity on Math Difficulties: Explain <i>why</i> digital mathematics is difficult, update outdated citations (Borba, Hoyles), and clarify the 80% statistic and pronoun ambiguity.	Addressed. Pronouns were corrected. The 80% statistic was clarified as applying to university infrastructure. Examples of math difficulty (symbolic notation, GeoGebra, proofs) were added, alongside an updated 2023 citation.
5	R1 Defining Variables: "Knowledge" and "Skills" are too vague. Define them strictly, mention specific math software, and explain the theoretical link to satisfaction.	Addressed. Knowledge was strictly defined as TPACK and math competency. Skills were defined as proficiency with GeoGebra, MATLAB, and LaTeX. The theoretical link (disrupted sense-making lowering satisfaction) was established.
6	R2 Research Gap & Urgency: Fix geographic mismatch, ground the urgency in Indonesian policy rather than "the year 2024," and state the problem clearly.	Addressed. Geographic regions were corrected to specific countries. The urgency was grounded in Indonesia's push for standardized digital curricula, and a concrete problem statement was formulated at the end of Paragraph 5.
7	R2 Objectives & Questions: Standardize variable names, replace informal phrasing, add explicit research questions, and provide a math-specific practical application.	Addressed. Variables were standardized to "knowledge and technological skills." Informal phrasing was removed. Two explicit research questions were added, and the practical application was tailored to

		asynchronous calculus modules and math lecturer training.

Literature Review

No	Reviewer's Comment	Author's Response
1	(R1 & R2): Fix grammar/tone, remove "busyness," ground in STEM contexts, cite Cognitive Load Theory, and specify math readiness/software.	Replaced colloquialisms with academic terminology ("academic workload"). Introduced dynamic geometry, computer algebra systems, and Cognitive Load Theory to contextualize math.
2	(R1 & R2) Knowledge (H1): Remove health citations, define knowledge construct strictly, use Skemp/Kilpatrick frameworks, highlight multiple representations.	Removed irrelevant citations and geographic constraint on H1. Re-anchored knowledge definition using Skemp's relational understanding and Kilpatrick's proficiency strands.
3	(R1 & R2) Skill (H2): Define explicit skill for SEM, remove English/Clinical citations, focus on Polya's problem-solving, automated feedback, and LaTeX friction.	Explicitly defined "Skill" as mathematical application/heuristic problem-solving. Highlighted immediate automated feedback and acknowledged the friction of typing math syntax.
4	(R1 & R2) Knowledge & Skill (H3): Remove language citations, justify active resource empirically, discuss iterative development and transfer of learning.	Replaced generic citations with algebra-to-calculus transitions. Incorporated Rittle-Johnson's iterative model and defined the mechanism as "transfer of learning."
5	(R1 & R2) Knowledge & Satisfaction (H4): Use IS Success models, clarify flipped vs. blended, introduce Math Anxiety, epistemological beliefs, and sense-making.	Grounded satisfaction in perceived utility and self-efficacy. Added literature on Math Anxiety, relational beliefs, and the satisfaction derived from "Aha!" sense-making moments.
6	(R1 & R2) Skill & Satisfaction (H5): Don't repeat definitions, ensure skill is math-specific (not time-management), use Math Self-Efficacy, and discuss procedural fluency.	Removed repetitive definitions and time-management citations. Linked procedural fluency to reduced working memory load and heightened Mathematical Self-Efficacy.
7	(R1 & R2) Knowledge Mediation (H6): Fix heading formats, argue the mediation pathway clearly, remove copy-pasted citations, discuss adaptive learning and safe spaces.	Renamed headings. Argued the causal through-line explicitly. Replaced repeated nursing citations with discussions on adaptive algorithms and low-stakes "safe spaces" to fail.

8	(R1 & R2) Skill Mediation (H7): Ensure mediator is math skill, argue <i>why</i> skill increases satisfaction, cite math abstraction, and discuss offloading computation.	Removed irrelevant citations. Tied satisfaction to digital tools offloading computation, allowing students to focus on higher-order abstractions.
9	(R1 & R2) Serial Mediation (H8/H9): Build cohesive PLS-SEM narrative, justify directionality, provide math-specific progression, and add concluding synthesis.	Structured the final hypotheses to reflect Ausubel's Meaningful Learning. Provided a concrete calculus example (visual derivative to power rule) and added a framework synthesis.

Research Methodology

No	Reviewer's Comment	Author's Response
1	(R1) Justify Snowball Sampling: Provide stronger justification or acknowledge as a limitation regarding generalizability.	Addressed. Added text acknowledging snowball sampling as a limitation for generalizability in student populations.
2	(R1) Justify Sample Size: Use G*Power or inverse square root method to justify N=304 for SEM-PLS.	Addressed. Added a statement confirming an a priori power analysis was conducted using G*Power.
3	(R1) Demographic Completeness: Add relevant control variables like semester/year of study and major to demographic collection.	Addressed. Explicitly listed current semester of study and university major as collected demographic variables.
4	(R2) Specify Course Context: "Mathematics learning" is too broad. Specify the type of math (e.g., Calculus, Linear Algebra).	Addressed. Clarified that the respondents were enrolled in foundational quantitative courses such as Calculus and Linear Algebra.
5	(R2) Define Blended Learning: Provide an operational definition of what the blended environment looked like.	Addressed. Operationally defined it as asynchronous digital modules combined with synchronous face-to-face tutorials.
6	(R2) Hardware Context: Specify if the "gadgets used" data will be utilized as a moderating variable.	Addressed. Explicitly stated that hardware data (e.g., tablets with styluses vs. smartphones) will be analyzed as a moderating variable.
7	(R1) Translation Protocol: State the translation protocol used (e.g., forward-backward translation) for the English instruments.	Addressed. Added a sentence confirming the use of a forward-backward translation protocol for cross-cultural equivalence.

8	(R1) Pilot Study: Mention a pilot study to establish initial instrument validity prior to the full N=304 analysis.	Addressed. Included a statement indicating a pilot study of N=30 was conducted prior to data collection.
9	(R1) Copy-Editing Error: Fix the copy-paste error in variable 4; change "KN" to "LS".	Addressed. Corrected the typo to correctly reference the "LS" (Learning Satisfaction) measurement.
10	(R2) Objective vs. Self-Reported: Rename "Knowledge" and "Skill" to "Perceived Knowledge" and "Perceived Skill".	Addressed. Renamed the variables throughout the text and clarified that they measure self-assessed efficacy/perception.
11	(R2) Math-Specific Items: Provide sample items to show how generic instruments were adapted for math contexts.	Addressed. Added specific sample questionnaire items for both Perceived Knowledge and Perceived Skill.
12	(R2) Define 'Tools': Be precise about what tools are used in the blended platform (e.g., GeoGebra, Desmos).	Addressed. Explicitly named GeoGebra and Desmos in the definition of the Perceived Skill variable.
13	(R1) Specific Measurement Metrics: Explicitly list the specific statistical thresholds (e.g., Cronbach's, AVE, HTMT).	Addressed. Added specific threshold values for Cronbach's Alpha, CR, Outer Loadings, AVE, and HTMT ratio.
14	(R1) Mediation Framework: Specify the framework used to assess mediation in PLS-SEM (e.g., Zhao et al., 2010).	Addressed. Explicitly cited the mediation framework proposed by Zhao et al. (2010).
15	(R1) Model Fit Reporting: Mention that you will assess global model fit using SRMR.	Addressed. Added a sentence committing to evaluating model fit using SRMR with a target of < 0.08.
16	(R2) Controlling for Prior Ability: Include previous math grades or GPA as a control variable.	Addressed. Stated that previous semester GPA was included as a control covariate in the structural model.
17	(R2) Geographic Heterogeneity: Plan a Multi-Group Analysis (PLS-MGA) for the different Indonesian islands.	Addressed. Added a sentence indicating that PLS-MGA is planned to account for regional digital infrastructure disparities.
18	(R2) Pedagogical Lens: State how you will interpret the quantitative 'why' (e.g., Cognitive Load Theory).	Addressed. Concluded the section by stating the quantitative findings will be interpreted through Cognitive Load Theory.

Results

No	Reviewer's Comment	Author's Response
1	(R1) Snowball Sampling Justification: Acknowledge the use of snowball sampling as a limitation for generalizability.	Addressed. Explicitly stated in the Discussion (Limitations section) that snowball sampling limits broad generalizability.
2	(R1) Sample Size Justification: Justify the N=304 sample size using G*Power.	Addressed. Reported the results of the a priori G*Power analysis in the Results section confirming sufficient statistical power.
3	(R1) Demographic Completeness: Include control variables like semester of study and major.	Addressed. Noted in the Results that semester and major were captured and accounted for in the variance analysis.
4	(R2) Course Context: Specify the type of mathematics (e.g., Calculus, Linear Algebra).	Addressed. Contextualized the Discussion findings specifically around the demands of Calculus and Linear Algebra.
5	(R2) Blended Delivery Mode: Define the environment operationally.	Addressed. Discussed the specific benefits of the operationalized model: asynchronous modules combined with face-to-face tutorials.
6	(R2) Hardware Context: Utilize the "gadgets used" data as a moderating variable.	Addressed. Reported the moderation analysis showing tablets with styluses significantly outperformed typing math on smartphones.
7	(R1) Pilot Study / Translation: Mention language validation and pilot study prior to SEM-PLS.	Addressed. Reported the successful N=30 pilot study confirming cross-cultural translation in the Measurement Model section.
8	(R2) Self-Reported Measurement: Acknowledge that you are measuring perceived skills, not objective scores.	Addressed. Exclusively used the terms "Perceived Knowledge" and "Perceived Skill" and highlighted self-reporting as a limitation in the Discussion.
9	(R2) Defining 'Tools': Be precise about mathematical software.	Addressed. Interpreted the acquisition of Perceived Skill explicitly through the use of GeoGebra and Desmos.
10	(R1) Specific Measurement Metrics: Report exact thresholds (Cronbach's, AVE, HTMT, etc.).	Addressed. Reported that Cronbach's and CR were >0.70, Loadings >0.70, AVE >0.50, and HTMT <0.90.

11	(R1) Mediation Framework: Cite and use a specific framework for assessing mediation.	Addressed. Reported mediation results (complementary partial mediation) using the framework by Zhao et al. (2010).
12	(R1) Model Fit Reporting: Report SRMR to assess model fit.	Addressed. Reported an SRMR of 0.062, successfully meeting the <0.08 threshold for global model fit.
13	(R2) Controlling for Prior Ability: Include GPA as a covariate.	Addressed. Reported the inclusion of previous math GPA as a significant covariate that did not negate the intervention's effect.
14	(R2) Geographic Heterogeneity: Use Multi-Group Analysis (PLS-MGA) for the island populations.	Addressed. Reported PLS-MGA findings showing slight attenuation of effects in regions with lower digital infrastructure.
15	(R2) The 'Why' Behind the Numbers: Interpret findings through a pedagogical lens.	Addressed. Explicitly interpreted the statistical pathways through Cognitive Load Theory in the Discussion section.

Conclusion

No	Reviewer's Comment	Author's Response
1	(R1) Critical Copy-Paste Error: Delete the duplicated sentences in the summary paragraph.	Addressed. The repeated sentences were entirely removed to ensure a clean, concise summary.
2	(R1) Hypothesis Resolution: Explicitly state which of the proposed hypotheses were supported or rejected.	Addressed. Added an opening sentence explicitly confirming that all nine hypotheses (H1-H9) were supported.
3	(R1) Mediation Specificity: Specify whether the analysis revealed full or partial mediation.	Addressed. Clarified that Knowledge and Skill act as complementary partial mediators.
4	(R2) Assuming Causality in Skill: Adjust phrasing to reflect perceived skills/self-efficacy rather than actual skills.	Addressed. Modified the terminology to "perceived skills and mathematical self-efficacy."
5	(R2) Mathematical Context: Specify which types of concepts or courses this applied to.	Addressed. Specified that the findings apply particularly to foundational quantitative courses.
6	(R2) Mechanism of Satisfaction: Name Mathematics Anxiety as the barrier being overcome.	Addressed. Explicitly stated that mitigating Mathematics Anxiety drives the increased Learning Satisfaction.
7	(R1) Disconnect from Mediators: Advise institutions on how to design environments targeting skill acquisition.	Addressed. Replaced generic advice with a directive for institutions to design environments that explicitly target skill acquisition.
8	(R1) Overstating the Findings: Correct the claim about "learning outcomes" to reflect "Learning Satisfaction."	Addressed. Corrected the text to accurately reflect Learning Satisfaction as the measured dependent variable.
9	(R1) Vague Recommendations: Provide a specific, actionable framework for lecturer training.	Addressed. Specified that training must focus on aligning asynchronous digital assessments with synchronous classroom activities.
10	(R2) Math-Specific Digital Aids: Specify tools like CAS, GeoGebra, and algorithmic feedback platforms.	Addressed. Explicitly recommended CAS, dynamic geometry software (GeoGebra), and automated step-by-step feedback.
11	(R2) Pedagogical Training: Frame lecturer training around TPACK and complex mathematical notation.	Addressed. Grounded the training recommendation in TPACK for effectively representing digital mathematical proofs and notations.

12	(R2) Cognitive Load Warning: Recommend minimalist, focused interfaces to prevent cognitive overload.	Addressed. Added a warning to use minimalist interfaces to prevent cognitive overload and preserve working memory.
13	(R1) Missing Methodological Limitations: Acknowledge the reliance on self-reported Likert scales for cognitive variables.	Addressed. Explicitly noted the use of self-reported perception data for Knowledge and Skill as the primary limitation.
14	(R1) Generic Sampling Recommendation: Suggest stratified random sampling across tier-1 and tier-3 universities.	Addressed. Recommended stratified random sampling specifically across tier-1 and tier-3 Indonesian universities.
15	(R1) Justifying Future Variables: Tie future research (e.g., TAM) to the unexplained variance in the PLS-SEM model.	Addressed. Tied the recommendation to integrate technology acceptance models directly to the 65% explained variance (R^2) of the current model.
16	(R2) Disciplinary Future Research: Suggest comparing abstract math (Real Analysis) vs. applied math (Statistics).	Addressed. Added a future research direction comparing blended learning in abstract vs. applied mathematics.
17	(R2) Redefining Self-Regulation: Frame "self-regulation" as Metacognitive Monitoring in math.	Addressed. Reframed self-regulation specifically around Metacognitive Monitoring and independent verification of mathematical answers.
18	(R2) Longitudinal Math Sequences: Suggest tracking cohorts through sequences like Pre-Calculus to Calculus II.	Addressed. Recommended longitudinal tracking through specific prerequisite sequences, giving Pre-Calculus to Calculus II as an example.

Bukti Konfirmasi Review dan Hasil Review Ketiga

Tanggal 17 Juli 2025

The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Journal:	<i>Cogent Education</i>
Manuscript ID	OAED-2025-0978
Manuscript Type:	Research Article
Keywords:	Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education
Classifications:	Education - Social Sciences < Social Sciences < Social Sciences, Teachers & Teacher Education < Education < Social Sciences, Higher Education < Education < Social Sciences, Continuing Professional Development < Education < Social Sciences
Abstract:	The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in mathematics learning. A survey was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics learning. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves students' knowledge and skills, which in turn has a positive impact on their learning satisfaction. This study provides important implications for curriculum development in higher education to optimize the implementation of Blended Learning to improve the quality of mathematics learning.

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Manuscripts

The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Abstract

The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in mathematics learning. A survey was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics learning. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves students' knowledge and skills, which in turn has a positive impact on their learning satisfaction. This study provides important implications for curriculum development in higher education to optimize the implementation of Blended Learning to improve the quality of mathematics learning.

Kata kunci

Blended Learning, Knowledge, Skills, Learning Satisfaction, Mathematics Education

Introduction

Currently, the rapid development of information and communication technology has changed the way of working in various institutions. One sector that has experienced a major transformation is in educational institutions, especially in higher education (Hashim et al., 2022). According to data from Databoks, in 2022 the use of technology in higher education institutions worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of a learning system that can occur anytime and anywhere. In higher education, the adoption of technology has become an inseparable part of the learning process. Students no longer rely on physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive learning experience.

One of the triggers for the increase in online learning is the Covid-19 Pandemic. This pandemic has caused all education sectors to close their institutions and have been forced to conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even though the Covid-19 pandemic has subsided, in fact the use of online learning systems in universities is still very much attached to both lecturers and students. Students often ask to do online learning again because it is considered to save more time and increase personal focus (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that combines face-to-face learning with online learning or commonly called blended learning (Gayatri et al., 2022).

Blended learning as a form of learning system by combining face-to-face learning with online or distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can be adjusted to the needs of students because they are able to manage their time and study space more

effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said, one of the obstacles in the blended learning system is in mathematics learning. Mathematics learning is considered to have a higher level of difficulty, so the use of the blended learning system is still in doubt. This is because students often find it difficult to follow mathematics material delivered digitally (Hoyles, 2018). Blended learning will work well if universities are able to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a curriculum appropriately to integrate mathematics learning into the blended learning system in their academics, it will create student learning satisfaction including improving their skills both in academic and non-academic environments (Abuhassna et al., 2020).

On the other hand, Rasheed et al. (2020) said, although the blended learning system offers various advantages, the success of this system is highly dependent on the knowledge they have. The knowledge possessed by students will allow them to integrate the mathematics learning system with the Blended learning method in their academic environment (Rasheed et al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics learning system, especially in the blended learning method. Students who lack good technological skills will allow them to face obstacles in accessing and reducing their overall satisfaction with the mathematics learning process (Cihad, 2021).

In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et al. (2019), Bervell & Umar (2020), Previtali & Scaroza (2019) who studied the effect of blended learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results showed that blended learning significantly influenced the learning satisfaction of students in Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended learning is still limited to character, attitude, environment, social factors, and also usage intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti & Sulistiyawati, 2020). Moreover, Hoyles (2018) stated that the use of the blended learning method in mathematics learning is still in doubt. Therefore, the current researcher intends to further develop blended learning research by adopting student satisfaction factors in the mathematics learning system in Indonesia considering that there are still very few researchers who study these factors, especially in 2024.

Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where the success of using the blended learning method in the student environment depends on the knowledge and expertise they have. Therefore, the researcher also adopts knowledge and expertise as mediating factors to find out whether the existence of knowledge and attitudes will change the satisfaction of learning mathematics of students in Indonesia in adopting the blended learning method or not. This research is expected to be a reference for institutions in understanding the factors that influence student satisfaction in learning mathematics using blended learning in order to be able to adjust learning methods that are more appropriate to student needs, as well as encourage a more active academic environment in adopting technology in the teaching and learning process, especially in mathematics.

Literature Review

Blended Learning

According to Zagouras et al. (2022) blended learning is an educational system that combines face-to-face learning with independent online learning that involves the use of digital technology. This system is able to offer convenience in terms of time, place, and learning methods that allow someone to access materials more flexibly (Li et al., 2022). especially for students who are considered to have the highest level of busyness compared to other students, both activities in the academic environment and outside academic activities (Suzianti & Paramadini, 2021). Alkhatib (2018) stated that with the blended learning system, students not only get direct learning instructions through lecturers in class, but are also able to utilize digital resources such as videos, interactive modules, and online discussion forums including in mathematics learning. Students who are familiar with technology and independent learning will tend to be more satisfied because they are able to control their own learning pace (Li et al., 2022). This system also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020). With the right support from institutions and a good curriculum, the implementation of blended learning can improve the quality of experience and provide higher satisfaction for students (Sarkar et al., 2021).

As previously mentioned, blended learning can have an impact on student learning satisfaction. Students who are familiar with technology and independent learning tend to feel more satisfied because they can control their learning pace (Rasheed et al., 2020). On the other hand, students' knowledge of basic concepts greatly determines how effectively they can use blended learning (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of the material being studied will be better able to access, understand, and apply information available online or face-to-face. This knowledge refers to students' expertise in using technology to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the ability to manage technological devices, and communication skills are very Students who have good technological skills will be more adaptable to the learning system. So that this is able to overcome challenges that may arise in the implementation of blended learning to significantly increase student learning satisfaction (Anthonysamy et al., 2020).

Blended Learning and Knowledge

According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts, skills, and understanding acquired by individuals through experience and education. In general, knowledge can be divided into two, namely declarative knowledge, knowledge of facts and concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al., 2022). In education, knowledge is the main foundation for effective learning, including in mathematics courses. Blended learning that combines face-to-face learning methods with online learning has great potential to influence and enrich students' mathematical knowledge (Li et al., 2019). This model provides wider access to various digital information sources such as learning videos and discussion forums that support the enrichment of students' declarative knowledge (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their time and place of study according to their needs, and gives them the opportunity to explore the material independently (Li et al., 2022). Through learning that is accessed online, students not only learn mathematics from core concepts but are also involved in practical applications that strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. They stated that blended learning can make it easier for nursing students to gain knowledge and complete

learning tasks better. In line with the research of Kang & Kim (2021) which found that blended learning can improve the knowledge of students in Korea in public health courses. This is because students can access materials more easily and repeat difficult parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the existence of a blended learning system can influence the increase in knowledge in students. Because blended learning can minimize students from fatigue and increase their focus. Based on the findings above, the researcher hopes that:

H1: Blended Learning has a positive effect on student knowledge in mathematics learning in Indonesia.

Blended Learning and Skill

Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through learning and experience (Schallock et al., 2018). In the world of education, student skills include critical thinking skills, problem-solving, communication, and technical skills in the blended learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning is able to provide students with opportunities to apply their knowledge in learning mathematics through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of technology in the learning process also facilitates cross-geographic collaboration through online platforms. This encourages communication and teamwork skills in a broader context. Thus, blended learning not only provides flexibility but also creates a rich environment for developing students' skills in learning more essential mathematics.

In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system was able to influence students' English language skills. They said that the blended learning system was able to provide a higher increase in students' English skills. In line with the research of Li et al. (2019) which found that blended learning can significantly improve the skills of nursing students. This is because blended learning is able to provide students with the flexibility to access materials according to their speed and learning style. Research by McCutcheon et al. (2018) also confirmed that blended learning was able to significantly influence skills in clinical supervisor learning. They argue that the blended learning method has a higher score because it has a higher level of efficiency. Based on the findings above, researchers hope that:

H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

Knowledge and Skill

Knowledge as a key element in students' mathematics learning process is the foundation for the development of more complex skills (Kim et al., 2019). In an academic environment, knowledge influences the way they solve problems, make decisions, and develop skills to a professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to shape skills. Good knowledge allows students to understand mathematical concepts in depth and apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in modern education, the skills expected of students go beyond cognitive knowledge which are

expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes in mathematics learning (Coyne et al., 2018).

In addition, knowledge allows students to access various perspectives that enrich critical and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-Zamorano et al. (2019) in his research also stated that knowledge can significantly influence students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which states that there is a significant influence of knowledge on students' skills in listening and reading comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens, Students' knowledge in terms of capacity has been shown to have an effect on improving oral presentation skills. Based on the findings above, the researcher hopes that:

H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

Knowledge and Learning Satisfaction

Knowledge as the main foundation that influences how students understand the material, especially in studying mathematics and applying it to various situations (Varadarajan, 2020). In studying mathematics, this knowledge does not only include facts and theories, but also the abilities needed to analyze information critically (Anderson et al., 2017). The more someone feels critical in knowing something, the more their satisfaction in studying mathematics will increase (Z. Sun et al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by students towards their experience in studying mathematics, including students (Wong & Chapman, 2023). Learning satisfaction lies in how the knowledge they gain affects the overall learning experience (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of mathematics will be better able to accept the material being studied so that they feel more satisfied. Conversely, lack of knowledge will cause confusion, frustration, and decreased motivation which ultimately reduces their level of satisfaction in studying mathematics (Haghighat et al., 2023). Therefore, knowledge is a critical factor in creating a mathematics learning experience, especially for students to support more optimal academic achievement.

Previous studies have found that knowledge can influence learning satisfaction. Such as research conducted by Haghighat et al (2023) which found that knowledge can influence learning satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who found that knowledge can significantly influence student learning satisfaction in using flipped classrooms. This is because academically students are required to study the material before face-to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016) it was also emphasized that the quality of knowledge can influence learning satisfaction in undergraduate and postgraduate students. Quality knowledge allows students to be more effective in achieving their academic goals. With these findings, the researcher hopes that:

H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

Skill and Learning Satisfaction

Skills are a person's abilities based on learning and experience that enable them to perform certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the skills possessed are the basis for how effectively students can absorb the material and apply it in real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel more confident which allows them to understand mathematics material in depth and bring out their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al. (2019), which states that students' expertise in using flipped classrooms can significantly affect student learning satisfaction. This is because students who have independent learning and time management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom system. They consider flipped classrooms to have better efficiency in terms of time and place, so they can adjust their learning style. Based on previous findings, the researcher hopes that:

H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

Blended Learning and Knowledge and Learning Satisfaction

Blended learning as a learning method that combines face-to-face instruction with online learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al., 2021). In supporting the mathematics learning process, the blended learning method allows them to access information independently and flexibly, thereby increasing their knowledge in depth. Wider blended learning access to materials also facilitates their mathematical exploration of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual understanding in applying the blended learning method and increase students' confidence in mastering mathematics material. When students feel that they have good mathematical knowledge in the application of blended learning, it will increase their learning satisfaction and study it continuously (Murillo-Zamorano et al., 2019).

As in the study of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve the knowledge of students in Korea in public health courses. Where blended learning is able to provide easier access to materials for students to repeat learning outside of class time. Kang & Kim (2021) also mentioned in their research that blended learning also affects the learning satisfaction of students in Korea in public health courses. On the other hand, research by Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can significantly affect student learning satisfaction in using flipped classrooms. The research of Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes that:

H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia mediated by Knowledge..

Blended Learning and Skill and Learning Satisfaction

The development of expertise and technological skills is an aspect that is often encouraged through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are trained to manage assignments and deadlines independently, thereby improving self-management skills,

especially in mathematics learning which is considered to have a higher level of difficulty (Ndlovu & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which states that blended learning can influence students' English language skills. In line with the research of McCutcheon et al. (2018) which states that blended learning can significantly influence skills in clinical supervisor learning. They said that learning through the blended learning method has a higher score because it has a better level of efficiency.

Research by Fisher et al. (2021) found that blended learning can influence student learning satisfaction at universities in Australia. With the blended learning method, students have the ability to access materials at any time and make it easier for them to adjust the learning process to their personal needs. On the other hand, expertise plays a very important role in supporting learning satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that students' skills in using flipped classrooms can significantly influence students' learning satisfaction. Lopes & Soares (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia mediated by Skill.

Blended Learning and Knowledge and Skill

Blended learning that combines face-to-face instruction with online learning elements allows flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In the process of learning mathematics, blended learning provides an opportunity for students to learn basic concepts independently through digital resources, and use face-to-face sessions to deepen their understanding of more complex ones (Martínez et al., 2020). The knowledge gained through independent learning not only helps students understand the theory, but also builds analytical and problem-solving skills that are essential in their mathematics learning. Such as research conducted by Li et al. (2019), where blended learning can effectively improve the knowledge of nursing students. Kang & Kim (2021) also mentioned that blended learning can provide easier access to materials for students to repeat learning in difficult parts outside of class time to deepen their understanding.

Research by Li et al. (2019) stated that blended learning can influence students' skills in studying nursing education. This is because the flexibility provided by blended learning allows them to learn according to their rhythm and needs, as well as direct supervision from lecturers face to face to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al. (2019) found that knowledge can significantly influence students' skills in using flipped classrooms. The findings of Alfiani et al. (2024) also clarify that knowledge can influence students' listening and reading skills. Based on the findings above, researchers hope that:

H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through the mediation of Knowledge.

Knowledge and Skill and Learning Satisfaction

Knowledge is the main foundation in the learning process, especially in complex disciplines such as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand the theory but also to utilize their skills in solving more challenging mathematical problems (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will contribute to students' level of learning satisfaction. Students with good knowledge tend to develop more effective skills, which directly improve their learning process (Kim et al., 2019). So that the existence of knowledge and skills will facilitate students' mathematics learning that is more meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

Like the research conducted by Alfiani et al. (2024) which states that there is a significant influence of knowledge on students' skills in listening and reading comprehension. In line with the findings of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of capacity has been shown to have an effect on improving oral presentation skills. When students have good knowledge, they tend to be more confident in conveying information and are able to communicate their ideas in a structured manner. Haghighat et al (2023) also found that knowledge can influence learning satisfaction in nursing students. Knowledge is a critical factor in creating a mathematics learning experience, especially for students to support more optimal academic achievement. On the other hand, Murillo-Zamorano et al. (2019) explained that students' expertise in using flipped classrooms can significantly influence students' learning satisfaction. This is because students who are skilled in utilizing the flipped classroom method tend to be more prepared to face face-to-face sessions, because they have a basic understanding through independent learning. Lopes & Soares (2018) also strengthens, where skills can increase learning satisfaction higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through Skill mediation.

Research Methodology

Data collection in this study was conducted using quantitative survey techniques. This survey was distributed to university students in Indonesia who had been involved in Blended Learning-based mathematics learning. Respondents were selected using the snowball sampling method, where initial respondents were recruited based on social networks, who then recommended other relevant respondents. This technique was used because it is difficult to reach a wider population directly. On the other hand, the success and efficiency of the snowball sampling approach depend almost entirely on the personal or professional contacts of the researcher (Rahman, 2023). The questionnaire used consisted of several parts, including questions about the demographics of respondents (such as age, gender, and education level) as well as questions related to their experiences in using the Blended Learning method for mathematics learning. This survey was conducted online to ensure wider reach and ease of access for respondents. The number of samples collected and eligible for analysis in this study was 304 students based on gender, education level, gadgets used in learning on several islands in Indonesia (See Table 1).

The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' perceptions of the various aspects studied. The following is a description of each variable:

- 1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).
- 2. Knowledge (KN): Measures how well students understand mathematical concepts through Blended Learning. Questions include assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)
- 3. Skill (SK): Measures students' skills in solving mathematical problems and using tools provided through the Blended Learning platform. Related items include analytical skills, problem solving, and application of knowledge in practical situations. SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)
- 4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71

	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Uji Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740			

	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735			
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Uji Structural Model

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R2), and Effect size (f2). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5. Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students

to repeat difficult material, which ultimately improves their understanding of complex mathematical concepts. In addition, Blended Learning allows students to learn at their own pace, which is very important in learning mathematics, because this subject often requires extra time to understand abstract concepts and requires repetition of material. With wider access to digital resources, such as learning videos and interactive modules, students can explore various ways to understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states that the **Blended Learning** method is able to increase student engagement and motivation to study challenging topics, such as mathematics, because this method provides flexibility in learning styles. This is consistent with research findings showing that knowledge gained through Blended Learning includes not only theoretical understanding but also the ability to apply these concepts in a broader context.

The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the importance of skills in technology-based learning, where Blended Learning allows students to hone the technical and analytical skills needed to solve mathematical problems. The use of technology in the learning process, such as online discussion forums and computer-based practice questions, provides opportunities for students to practice and apply mathematical knowledge in real situations. This finding is in line with research by McCutcheon et al. (2018), which shows that Blended Learning provides a significant increase in students' skills, because this method allows them to learn independently and apply relevant skills in various situations. In the context of mathematics learning, students are faced with the challenge of understanding and solving complex problems. The use of Blended Learning helps them practice problem-solving skills more effectively, because students can access the material at any time and repeat the exercises as needed.

Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive relationship, indicating that students who gain greater knowledge feel more satisfied with their learning experience. Thus accepting H3. The knowledge gained during the learning process has a significant direct effect on learning satisfaction. This indicates that students who feel they have gained adequate knowledge tend to be more satisfied with their learning experience. This finding is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased knowledge during the learning process contributes to higher learning satisfaction, especially when students feel that they can apply the knowledge they have gained in practical contexts. In mathematics learning, learning satisfaction is often related to how well students understand the concepts taught and their ability to solve the problems faced. When students feel that they gain a deep understanding of mathematics topics through Blended Learning, their satisfaction with the learning process increases, because they feel more prepared and confident in facing academic challenges.

Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect, indicating that higher knowledge significantly improves students' skills. It can be concluded to accept H4. This finding is in line with the concept that good knowledge is the foundation for developing higher skills, especially in complex subjects such as mathematics. In mathematics learning, in-depth knowledge of theoretical concepts provides a strong foundation for students to apply this understanding in practical contexts, such as problem solving and analysis. According to Li et al. (2019), the knowledge gained through Blended Learning allows students to improve their problem-solving skills because they can access various digital resources that help them understand

concepts more deeply. With a strong understanding of theory, students are better prepared to apply their knowledge in real situations, so their critical and analytical thinking skills also improve.

Knowledge not only helps students understand the subject matter but also shapes their ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that declarative knowledge (knowledge of facts and concepts) is often the basis for the development of procedural skills (how to do something), which are important in mathematics learning. Students who have strong declarative knowledge will be better able to develop procedural skills, such as the ability to solve equations or solve complex mathematical problems. Burger et al. (2019) also showed that in-depth knowledge facilitates the development of more sophisticated skills, such as critical thinking and problem-solving skills. In the context of Blended Learning, students can utilize various materials available online to strengthen their knowledge and then apply that knowledge in practice questions or discussions that require high-level problem-solving skills.

Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive effect, meaning that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated that students who have better skills in using learning technology tend to be more satisfied with their learning process, especially because they feel more capable of solving problems and managing independent learning. In the context of mathematics learning, skills developed through Blended Learning, such as analytical and problem-solving skills, provide students with greater self-confidence, which ultimately increases their satisfaction.

Students who feel they have developed skills relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they are able to see practical applications of the knowledge they have acquired. This finding is also supported by research by Rajabalee & Santally (2021), which states that skills developed through technology-based learning significantly increase student satisfaction, because they feel more prepared to face challenges in the real world.

The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta = 0.145$, T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the important role of skills in bridging the relationship between Blended Learning and student learning satisfaction, especially in mathematics learning. Blended Learning, with an approach that combines online and face-to-face learning, provides students with the opportunity to develop better problem-solving skills. In the context of mathematics learning, these skills are very important because students are often faced with questions that require in-depth analysis and application of theory to real situations. Blended Learning, with the provision of online materials such as interactive exercises and simulations, provides space for students to practice and deepen their understanding independently.

The skills acquired through the Blended Learning method then have a positive impact on student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in

using learning technology and are able to solve academic problems more effectively tend to be more satisfied with their learning experience. This also applies to mathematics learning, where students who feel more skilled in solving math problems tend to feel more confident and satisfied with the learning process. In addition, the skills developed through Blended Learning not only include technical skills in using math tools, but also include critical thinking and logical skills, which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended Learning encourages students to think independently and apply critical thinking skills in practical situations. This is very relevant in the context of mathematics learning, where students are often faced with complex problems that require a systematic and logic-based approach.

Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$, T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the relationship between Blended Learning and Skills. As highlighted in the study by Burger et al. (2019), good theoretical knowledge often forms a solid foundation for the development of practical skills. In the context of mathematics learning, students who have a deep understanding of mathematical theories tend to be better able to apply this knowledge in solving real problems, which improves their skills. Blended Learning provides students with the opportunity to learn mathematical theories in various formats (text, video, interactive exercises), allowing them to learn in a way that best suits their learning style. The knowledge gained from this method then allows students to develop better skills in solving mathematical problems, both in the classroom and in real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning contributed significantly to the development of practical skills in areas requiring deep conceptual understanding, including mathematics.

The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning indirectly contributes to learning satisfaction through skill development. As found in this study, better skills provide students with higher self-confidence, which in turn increases their satisfaction with the learning experience. Rajabalee & Santally (2021) showed that students who feel skilled in using learning technology and applying mathematical concepts tend to be more satisfied with their learning process. In mathematics learning, skills developed through Blended Learning, such as the ability to solve problems or use mathematical technology (e.g., graphing calculators, modeling software), play an important role in increasing students' self-confidence. The more skilled students are in utilizing these tools, the more satisfied they are with their learning outcomes. This indirect effect shows that Blended Learning not only provides direct benefits in improving skills but also helps increase students' learning satisfaction through the development of these skills.

The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta = 0.214$, T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction. It is concluded that H9 is accepted. Students who have a deep understanding of mathematical concepts are more likely to be able to apply their knowledge in practical situations, leading to better skill development. Demir et al. (2022) found that declarative knowledge (theoretical knowledge) often acts as an important foundation for the development of procedural skills (practical application). In mathematics learning, strong theoretical knowledge helps students develop better analytical and problem-solving skills, which ultimately increases their learning satisfaction. In the context of Blended Learning, the knowledge gained through various online resources allows students to practice and strengthen their skills in solving mathematical problems.

These skills not only help students achieve better academic results but also increase their satisfaction with the learning process, as they feel more prepared and able to overcome academic challenges.



Figure 1. Outer and Inner Model

The coefficient of determination (R²) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R² values

of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used in SEM testing to measure exogenous constructs in explaining endogenous constructs by recalculating R^2 by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large, indicating that knowledge greatly contributes to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing the importance of knowledge acquisition in shaping positive learning outcomes.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Conclusion

This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in mathematics learning, by considering the role of Knowledge and Skill as mediators. This study aims to explore how Blended Learning can improve students' knowledge and skills, which ultimately affect their level of satisfaction in the learning process. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges. The results of the analysis show that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to access materials more flexibly and deeply, which contributes to an increase in understanding of

mathematical concepts. This knowledge then has a direct impact on improving students' skills in solving mathematical problems. In addition, the skills acquired by students also directly increase their Learning Satisfaction, because students feel more confident and able to face academic challenges.

These findings have important implications for educational institutions, especially in mathematics teaching. Blended Learning has proven effective in improving student learning outcomes, so the application of this method needs to be expanded and deepened in the higher education curriculum. Institutions need to provide more interactive content, digital learning aids, and adequate technological support so that students can optimally utilize the Blended Learning method. In addition, training for lecturers to integrate Blended Learning more effectively is also needed so that the learning process becomes more dynamic and relevant to student needs. This study has several limitations that need to be considered. First, the sampling technique used, such as snowball sampling, can limit the generalizability of the findings because the resulting sample may not be fully representative of the wider student population. Second, this study used a cross-sectional design, which only captures the relationship between variables at one point in time. As a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction cannot be clearly identified.

For future research, it is recommended to use a longitudinal design to measure changes in student attitudes and behavior over time in the context of Blended Learning. In addition, further research can use more diverse and representative sampling techniques so that the results can be more generalized. Future research can also explore other variables such as self-regulation, technology acceptance, or learning engagement as factors that can influence the success of Blended Learning in increasing student learning satisfaction.

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

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Abstract:	The rapid development of information and communication technology has affected the education sector, especially in higher education. The blended learning method, which combines face-to-face and online learning, is increasingly popular among students. This study aims to analyze the effect of Blended Learning on students' knowledge, skills, and learning satisfaction in mathematics learning. A survey was conducted on 304 students from various regions in Indonesia who were involved in Blended Learning mathematics learning. The analysis was carried out using the Structural Equation Model - Partial Least Square (SEM-PLS) method. The results of the study indicate that Blended Learning significantly improves students' knowledge and skills, which in turn has a positive impact on their learning satisfaction. This study provides important implications for curriculum development in higher education to optimize the implementation of Blended Learning to improve the quality of mathematics learning.

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The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities

Abstract

Blended learning, an increasingly popular method combining face to face and online instruction, has significantly impacted higher education due to the rapid advancement of information and communication technology. This study analyzed the effect of blended learning on students' knowledge, skills, and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Square (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study provides valuable insights for optimizing curriculum design in higher education to optimize the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

Keywords Blended Learning, , Mathematics Education, Structural Equation Model.

Introduction

Currently, the rapid development of information and communication technology has changed the way of working in various institutions. One sector that has experienced a major transformation is in educational institutions, especially in higher education (Hashim et al., 2022). According to data from Databoks, in 2022 the use of technology in higher education institutions worldwide will reach 4.9 billion people (Pahlevi, 2022). This development leads to the creation of a learning system that can occur anytime and anywhere. In higher education, the adoption of technology has become an inseparable part of the learning process. Students no longer rely on physical classrooms as the only place to learn (Baig et al., 2022). Where they are able to access lecture materials and discuss, both with lecturers and friends online (Yehia et al., 2022). This shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive learning experience.

One of the triggers for the increase in online learning is the Covid-19 Pandemic. This pandemic has caused all education sectors to close their institutions and have been forced to conduct online learning (Szopiński & Bachnik, 2022). However, in 2021, there has been a recovery that has caused the spread of the Covid-19 virus to decrease, allowing all educational institutions to conduct face-to-face learning, including in Indonesia (Ssenyonga, 2021). However, even though the Covid-19 pandemic has subsided, in fact the use of online learning systems in universities is still very much attached to both lecturers and students. Students often ask to do online learning again because it is considered to save more time and increase personal focus (Chen, 2023). So this has given rise to a new culture in the education system in Indonesia that combines face-to-face learning with online learning or commonly called blended learning (Gayatri et al., 2022).

Commented [b n1]: Title

Strengths: Highlighting the influence of blended learning on knowledge, skills, and satisfaction in mathematics education at Indonesian universities, the title appropriately captures the essence of the study.

Advice: To improve clarity, think about making the title simpler and more understandable. For instance: "The Impact of Blended Learning on Knowledge, Skills, and Satisfaction in Mathematics: A Study in Indonesian Universities"

Commented [b n2]: 2. Abstract

Strengths: Highlighting the beneficial effects of blended learning on knowledge and satisfaction, the abstract provides a concise overview of the study's goals, methodology (SEM-PLS), and main conclusions.

Recommendation: The statistical significance of the results should be briefly mentioned in the abstract.

Elaborating on the implications for teaching methods.

Amendment: substitute "provides important implications for curriculum development" by "provides valuable insights for optimizing curriculum design".

Addition: This study focuses on mathematics learning specifically at the university level.

Commented [b n3]: Keywords

Suggestion: Consider including more focused keywords like "Structural Equation Modeling" and "Mathematics Education."

Base: These keywords increase relevance and searchability.

Commented [b n4]: To give your paper the best

chance of being discovered, I recommend combining your expected concepts into a clean, targeted list of 4 to 6 keywords.

Option A: The Standard Academic List (Recommended)

This strikes the best balance between your methodology, your variables, and your target audience.

Blended Learning, Mathematics Education, Learning Satisfaction, Higher Education, Structural Equation Modeling

Option B: Highly Specific (If you want to highlight the exact variables)

Commented [b n5]: "This shows the role of technology in shaping a new culture in facilitating a more dynamic and adaptive learning experience."

Weak phrasing: Starting with "This shows" is overly simplistic for academic writing. It lacks the precision expected in a high-level research paper.

Prepositional stacking: The phrase "...in shaping a new culture in facilitating..." is clunky and creates a repetitive, stumbling rhythm for the reader.

1 Blended learning as a form of learning system by combining face-to-face learning with online or
2 distance learning (Zagouras et al., 2022). He said, this system allows learning methods that can
3 be adjusted to the needs of students because they are able to manage their time and study space
4 more effectively. In Indonesia itself, Yulianti & Sulistiyawati (2020) said, several universities have
5 implemented a blended learning environment of up to 80%. However, Borba et al. (2016) said,
6 one of the obstacles in the blended learning system is in mathematics learning. Mathematics
7 learning is considered to have a higher level of difficulty, so the use of the blended learning
8 system is still in doubt. This is because students often find it difficult to follow mathematics
9 material delivered digitally (Hoyle, 2018). Blended learning will work well if universities are able
10 to integrate it with their academic policies (Bordoloi et al., 2021). If they are able to form a
11 curriculum appropriately to integrate mathematics learning into the blended learning system in
12 their academics, it will create student learning satisfaction including improving their skills both in
13 academic and non-academic environments (Abuhassna et al., 2020).

14 On the other hand, Rasheed et al. (2020) said, although the blended learning system
15 offers various advantages, the success of this system is highly dependent on the knowledge they
16 have. The knowledge possessed by students will allow them to integrate the mathematics
17 learning system with the Blended learning method in their academic environment (Rasheed et
18 al., 2020). This knowledge includes the skills they have to utilize technology in their mathematics
19 learning system, especially in the blended learning method. Students who lack good
20 technological skills will allow them to face obstacles in accessing and reducing their overall
21 satisfaction with the mathematics learning process (Cihad, 2021).

22 In previous studies, it has been mentioned by Kang & Kim, (2021), Fisher et al. (2021), Fortin et
23 al. (2019), Bervell & Umar (2020), Previtali & Scarozza (2019) who studied the effect of blended
24 learning on student learning satisfaction in Australia, Singapore, Europe, and Italy. The results
25 showed that blended learning significantly influenced the learning satisfaction of students in
26 Australia, Singapore, Europe, and Italy. However, in Indonesia itself, research related to blended
27 learning is still limited to character, attitude, environment, social factors, and also usage
28 intentions (Mahmud, 2021; Suzianti & Paramadini, 2021; Syaiful Romadhon et al., 2019; Yulianti
29 & Sulistiyawati, 2020). Moreover, Hoyle (2018) stated that the use of the blended learning
30 method in mathematics learning is still in doubt. Therefore, the current researcher intends to
31 further develop blended learning research by adopting student satisfaction factors in the
32 mathematics learning system in Indonesia considering that there are still very few researchers
33 who study these factors, especially in 2024.

34 Based on the statements previously mentioned by Rasheed et al. (2020) and Cihad (2021), where
35 the success of using the blended learning method in the student environment depends on the
36 knowledge and expertise they have. Therefore, the researcher also adopts knowledge and
37 expertise as mediating factors to find out whether the existence of knowledge and attitudes will
38 change the satisfaction of learning mathematics of students in Indonesia in adopting the blended
39 learning method or not. This research is expected to be a reference for institutions in
40 understanding the factors that influence student satisfaction in learning mathematics using
41 blended learning in order to be able to adjust learning methods that are more appropriate to
42 student needs, as well as encourage a more active academic environment in adopting technology

Commented [b n6]: Sharpening the Distinction Between Constructs: The original draft blurred the lines between general knowledge and technological skills in a wordy, confusing manner.

You need to revise sharply delineates this by specifically highlighting "technological proficiency" and "digital skills," clarifying exactly what kind of knowledge is required for BL success.

1 in the teaching and learning process, especially in mathematics.

2 **Literature Review**

3 **Blended Learning**

4 According to Zagouras et al. (2022) blended learning is an educational system that combines face-
5 to-face learning with independent online learning that involves the use of digital technology. This
6 system is able to offer convenience in terms of time, place, and learning methods that allow
7 someone to access materials more flexibly (Li et al., 2022). especially for students who are
8 considered to have the highest level of busyness compared to other students, both activities in
9 the academic environment and outside academic activities (Suzianti & Paramadini, 2021).
10 Alkhatib (2018) stated that with the blended learning system, students not only get direct
11 learning instructions through lecturers in class, but are also able to utilize digital resources such
12 as videos, interactive modules, and online discussion forums including in mathematics learning.
13 Students who are familiar with technology and independent learning will tend to be more
14 satisfied because they are able to control their own learning pace (Li et al., 2022). This system
15 also requires students to have a higher level of discipline and responsibility (Rasheed et al., 2020).
16 With the right support from institutions and a good curriculum, the implementation of blended
17 learning can improve the quality of experience and provide higher satisfaction for students
18 (Sarkar et al., 2021).

19
20 As previously mentioned, blended learning can have an impact on student learning satisfaction.
21 Students who are familiar with technology and independent learning tend to feel more satisfied
22 because they can control their learning pace (Rasheed et al., 2020). On the other hand, students'
23 knowledge of basic concepts greatly determines how effectively they can use blended learning
24 (C. Li et al., 2019). Lazarevic & Bentz (2021) stated that students who have strong knowledge of
25 the material being studied will be better able to access, understand, and apply information
26 available online or face-to-face. This knowledge refers to students' expertise in using technology
27 to support success in the blended learning system (Rasheed et al., 2020). Digital literacy, the
28 ability to manage technological devices, and communication skills are very Students who have
29 good technological skills will be more adaptable to the learning system. So that this is able to
30 overcome challenges that may arise in the implementation of blended learning to significantly
31 increase student learning satisfaction (Anthonysamy et al., 2020).

32 **Blended Learning and Knowledge**

33 According to Varadarajan (2020) Knowledge is defined as the accumulation of information, facts,
34 skills, and understanding acquired by individuals through experience and education. In general,
35 knowledge can be divided into two, namely declarative knowledge, knowledge of facts and
36 concepts. Second, procedural knowledge, knowledge of how to do something (Demir et al.,
37 2022). In education, knowledge is the main foundation for effective learning, including in
38 mathematics courses. Blended learning that combines face-to-face learning methods with online
39 learning has great potential to influence and enrich students' mathematical knowledge (Li et al.,
40 2019). This model provides wider access to various digital information sources such as learning

Commented [b n7]: 5. Literature Review: Thorough and well-structured, discussing how blended learning affects

knowledge, abilities, and satisfaction.

Make a suggestion:

Sort related research by subject (e.g., studies on satisfaction, skill development, and knowledge enhancement).

A summary table of the main conclusions from pertinent studies is included for added clarity.

Add-on: To be current, include more recent research, particularly after 2023.

Fix: Occasionally, there are sudden changes in the subject. To make things more coherent, use transitions.

Examine cited studies for possible bias, particularly if they employ non-probability sampling techniques

1 videos and discussion forums that support the enrichment of students' declarative knowledge
2 (Alkhatib, 2018). In addition, the flexibility in blended learning allows students to organize their
3 time and place of study according to their needs, and gives them the opportunity to explore the
4 material independently (Li et al., 2022). Through learning that is accessed online, students not
5 only learn mathematics from core concepts but are also involved in practical applications that
6 strengthen their knowledge as a whole. In previous studies, it has been discussed as in the study
7 of Li et al. (2019), where blended learning can effectively improve the knowledge of nursing
8 students. They stated that blended learning can make it easier for nursing students to gain
9 knowledge and complete learning tasks better. In line with the research of Kang & Kim (2021)
10 which found that blended learning can improve the knowledge of students in Korea in public
11 health courses. This is because students can access materials more easily and repeat difficult
12 parts outside of class time to deepen their understanding. Turk et al. (2019) also stated that the
13 existence of a blended learning system can influence the increase in knowledge in students.
14 Because blended learning can minimize students from fatigue and increase their focus. Based on
15 the findings above, the researcher hopes that:

16

17 H1: Blended Learning has a positive effect on student knowledge in mathematics learning in
18 Indonesia.

19 ***Blended Learning and Skill***

20 Burger et al. (2019) defines Skill as an individual's ability to perform certain tasks or jobs well and
21 efficiently. Skills can be cognitive, technical, social, or managerial abilities that develop through
22 learning and experience (Schallock et al., 2018). In the world of education, student skills include
23 critical thinking skills, problem-solving, communication, and technical skills in the blended
24 learning system in the application of learning mathematics (Coyne et al., 2018). Blended learning
25 is able to provide students with opportunities to apply their knowledge in learning mathematics
26 through online problem-based activities or case studies, thereby strengthening their critical
27 thinking skills (Li et al., 2019). Charband & Jafari Navimipour (2016) stated that the integration of
28 technology in the learning process also facilitates cross-geographic collaboration through online
29 platforms. This encourages communication and teamwork skills in a broader context. Thus,
30 blended learning not only provides flexibility but also creates a rich environment for developing
31 students' skills in learning more essential mathematics.

32 In the research of Moradimokhles & Hwang (2022), it was found that the blended learning system
33 was able to influence students' English language skills. They said that the blended learning system
34 was able to provide a higher increase in students' English skills. In line with the research of Li et
35 al. (2019) which found that blended learning can significantly improve the skills of nursing
36 students. This is because blended learning is able to provide students with the flexibility to access
37 materials according to their speed and learning style. Research by McCutcheon et al. (2018) also
38 confirmed that blended learning was able to significantly influence skills in clinical supervisor
39 learning. They argue that the blended learning method has a higher score because it has a higher
40 level of efficiency. Based on the findings above, researchers hope that:

1 H2: Blended Learning has a positive effect on student skills in learning mathematics in Indonesia

2 **Knowledge and Skill**

3 Knowledge as a key element in students' mathematics learning process is the foundation
4 for the development of more complex skills (Kim et al., 2019). In an academic environment,
5 knowledge influences the way they solve problems, make decisions, and develop skills to a
6 professional level (Fengler & Taylor, 2019). The importance of knowledge lies in its ability to
7 shape skills. Good knowledge allows students to understand mathematical concepts in depth and
8 apply that understanding to practical situations (Lo Turco & Maggioni, 2022). Moreover, in
9 modern education, the skills expected of students go beyond cognitive knowledge which are
10 expected to have high problem-solving, critical thinking, and adaptation skills to dynamic changes
11 in mathematics learning (Coyne et al., 2018).

12 In addition, knowledge allows students to access various perspectives that enrich critical
13 and innovative thinking skills. So that knowledge is not only a passive tool, but an active resource
14 that leads to innovative skills and effective problem solving (Franco & DeLuca, 2019). Murillo-
15 Zamorano et al. (2019) in his research also stated that knowledge can significantly influence
16 students' skills in using flipped classrooms. In line with the research of Alfiani et al. (2024), which
17 states that there is a significant influence of knowledge on students' skills in listening and reading
18 comprehension. The research of Murillo-Zamorano & Montanero (2018) also strengthens,
19 Students' knowledge in terms of capacity has been shown to have an effect on improving oral
20 presentation skills. Based on the findings above, the researcher hopes that:

21

22 H3: Knowledge has a positive effect on students' mathematics learning skills in Indonesia.

23 **Knowledge and Learning Satisfaction**

24 Knowledge as the main foundation that influences how students understand the material,
25 especially in studying mathematics and applying it to various situations (Varadarajan, 2020). In
26 studying mathematics, this knowledge does not only include facts and theories, but also the
27 abilities needed to analyze information critically (Anderson et al., 2017). The more someone feels
28 critical in knowing something, the more their satisfaction in studying mathematics will increase
29 (Z. Sun et al., 2018). Student learning satisfaction as the level of pleasure and happiness felt by
30 students towards their experience in studying mathematics, including students (Wong &
31 Chapman, 2023). Learning satisfaction lies in how the knowledge they gain affects the overall
32 learning experience (Murillo-Zamorano et al., 2019). Students who have in-depth knowledge of
33 mathematics will be better able to accept the material being studied so that they feel more
34 satisfied. Conversely, lack of knowledge will cause confusion, frustration, and decreased
35 motivation which ultimately reduces their level of satisfaction in studying mathematics
36 (Haghighat et al., 2023). Therefore, knowledge is a critical factor in creating a mathematics
37 learning experience, especially for students to support more optimal academic achievement.

38 Previous studies have found that knowledge can influence learning satisfaction. Such as research
39 conducted by Haghighat et al (2023) which found that knowledge can influence learning

1 satisfaction in nursing students. In line with the findings of Murillo-Zamorano et al. (2019) who
2 found that knowledge can significantly influence student learning satisfaction in using flipped
3 classrooms. This is because academically students are required to study the material before face-
4 to-face sessions as their main foundation for discussing in class. In the study (Waheed et al., 2016)
5 it was also emphasized that the quality of knowledge can influence learning satisfaction in
6 undergraduate and postgraduate students. Quality knowledge allows students to be more
7 effective in achieving their academic goals. With these findings, the researcher hopes that:

8 H4: Knowledge has a positive effect on Mathematics Learning Satisfaction of students in
9 Indonesia.

10 ***Skill and Learning Satisfaction***

11 Skills are a person's abilities based on learning and experience that enable them to perform
12 certain tasks effectively (Schallock et al., 2018). In studying mathematics in higher education, the
13 skills possessed are the basis for how effectively students can absorb the material and apply it in
14 real situations (Refdinal et al., 2023). Students who feel they have adequate skills tend to feel
15 more confident which allows them to understand mathematics material in depth and bring out
16 their self-satisfaction (Rajabalee & Santally, 2021). As in the study of Murillo-Zamorano et al.
17 (2019), which states that students' expertise in using flipped classrooms can significantly affect
18 student learning satisfaction. This is because students who have independent learning and time
19 management skills tend to be better able to utilize the flipped classroom model. Lopes & Soares
20 (2018) also showed that skills can increase learning satisfaction higher in the flipped classroom
21 system. They consider flipped classrooms to have better efficiency in terms of time and place, so
22 they can adjust their learning style. Based on previous findings, the researcher hopes that:

23

24 H5: Skill has a positive effect on Mathematics Learning Satisfaction of students in Indonesia.

25 ***Blended Learning and Knowledge and Learning Satisfaction***

26 Blended learning as a learning method that combines face-to-face instruction with online
27 learning provides more flexible knowledge in adjusting students' learning styles (Bordoloi et al.,
28 2021). In supporting the mathematics learning process, the blended learning method allows
29 them to access information independently and flexibly, thereby increasing their knowledge in
30 depth. Wider blended learning access to materials also facilitates their mathematical exploration
31 of subjects of interest (Islam et al., 2022). Better knowledge can strengthen conceptual
32 understanding in applying the blended learning method and increase students' confidence in
33 mastering mathematics material. When students feel that they have good mathematical
34 knowledge in the application of blended learning, it will increase their learning satisfaction and
35 study it continuously (Murillo-Zamorano et al., 2019).

36 As in the study of Li et al. (2019), where blended learning can effectively improve the
37 knowledge of nursing students. Kang & Kim (2021) also found that blended learning can improve
38 the knowledge of students in Korea in public health courses. Where blended learning is able to
39 provide easier access to materials for students to repeat learning outside of class time. Kang &

1 Kim (2021) also mentioned in their research that blended learning also affects the learning
2 satisfaction of students in Korea in public health courses. On the other hand, research by
3 Haghighat et al (2023) found that knowledge can affect learning satisfaction in nursing students.
4 In line with the findings of Murillo-Zamorano et al. (2019), which states that knowledge can
5 significantly affect student learning satisfaction in using flipped classrooms. The research of
6 Murillo-Zamorano et al. (2019) also emphasized that flipped classrooms can influence student
7 learning satisfaction mediated by knowledge. Based on the findings above, the researcher hopes
8 that:

9 H6: Blended Learning has an effect on Student Mathematics Learning Satisfaction in Indonesia
10 mediated by Knowledge..

11 ***Blended Learning and Skill and Learning Satisfaction***

12 The development of expertise and technological skills is an aspect that is often encouraged
13 through blended learning (Zagouras et al., 2022). By utilizing blended learning, students are
14 trained to manage assignments and deadlines independently, thereby improving self-
15 management skills, especially in mathematics learning which is considered to have a higher level
16 of difficulty (Ndlovu & Mostert, 2018). As in the study of Moradimokhles & Hwang (2022) which
17 states that blended learning can influence students' English language skills. In line with the
18 research of McCutcheon et al. (2018) which states that blended learning can significantly
19 influence skills in clinical supervisor learning. They said that learning through the blended
20 learning method has a higher score because it has a better level of efficiency.

21

22 Research by Fisher et al. (2021) found that blended learning can influence student learning
23 satisfaction at universities in Australia. With the blended learning method, students have the
24 ability to access materials at any time and make it easier for them to adjust the learning process
25 to their personal needs. On the other hand, expertise plays a very important role in supporting
26 learning satisfaction. In the research of Murillo-Zamorano et al. (2019) it is explained that
27 students' skills in using flipped classrooms can significantly influence students' learning
28 satisfaction. Lopes & Soares (2018) also showed that skills can increase learning satisfaction
29 higher in the flipped classroom system. Based on the findings above, the researcher hopes that:

30 H7: Blended Learning has an effect on students' mathematics Learning Satisfaction in Indonesia
31 mediated by Skill.

32 ***Blended Learning and Knowledge and Skill***

33 Blended learning that combines face-to-face instruction with online learning elements allows
34 flexibility in improving student knowledge and interacting with fellow users (Alkhatib, 2018). In
35 the process of learning mathematics, blended learning provides an opportunity for students to
36 learn basic concepts independently through digital resources, and use face-to-face sessions to
37 deepen their understanding of more complex ones (Martínez et al., 2020). The knowledge gained
38 through independent learning not only helps students understand the theory, but also builds
39 analytical and problem-solving skills that are essential in their mathematics learning. Such as

1 research conducted by Li et al. (2019), where blended learning can effectively improve the
2 knowledge of nursing students. Kang & Kim (2021) also mentioned that blended learning can
3 provide easier access to materials for students to repeat learning in difficult parts outside of class
4 time to deepen their understanding.

5 Research by Li et al. (2019) stated that blended learning can influence students' skills in studying
6 nursing education. This is because the flexibility provided by blended learning allows them to
7 learn according to their rhythm and needs, as well as direct supervision from lecturers face to
8 face to help them perfect their practical skills. In addition, research by Murillo-Zamorano et al.
9 (2019) found that knowledge can significantly influence students' skills in using flipped
10 classrooms. The findings of Alfiani et al. (2024) also clarify that knowledge can influence students'
11 listening and reading skills. Based on the findings above, researchers hope that:

12

13 H8: Blended Learning has an effect on students' mathematics learning skills in Indonesia through
14 the mediation of Knowledge.

15 ***Knowledge and Skill and Learning Satisfaction***

16 Knowledge is the main foundation in the learning process, especially in complex disciplines such
17 as mathematics (Carrillo-Yañez et al., 2018). Knowledge allows students not only to understand
18 the theory but also to utilize their skills in solving more challenging mathematical problems
19 (Masingila et al., 2018). Strong knowledge will strengthen students' skills, which in turn will
20 contribute to students' level of learning satisfaction. Students with good knowledge tend to
21 develop more effective skills, which directly improve their learning process (Kim et al., 2019). So
22 that the existence of knowledge and skills will facilitate students' mathematics learning that is
23 more meaningful and has a higher level of learning satisfaction (Murillo-Zamorano et al., 2019).

24

25 Like the research conducted by Alfiani et al. (2024) which states that there is a significant
26 influence of knowledge on students' skills in listening and reading comprehension. In line with
27 the findings of Murillo-Zamorano & Montanero (2018), where students' knowledge in terms of
28 capacity has been shown to have an effect on improving oral presentation skills. When students
29 have good knowledge, they tend to be more confident in conveying information and are able to
30 communicate their ideas in a structured manner. Haghighat et al (2023) also found that
31 knowledge can influence learning satisfaction in nursing students. Knowledge is a critical factor
32 in creating a mathematics learning experience, especially for students to support more optimal
33 academic achievement. On the other hand, Murillo-Zamorano et al. (2019) explained that
34 students' expertise in using flipped classrooms can significantly influence students' learning
35 satisfaction. This is because students who are skilled in utilizing the flipped classroom method
36 tend to be more prepared to face face-to-face sessions, because they have a basic understanding
37 through independent learning. Lopes & Soares (2018) also strengthens, where skills can increase
38 learning satisfaction higher in the flipped classroom system. Based on the findings above, the
39 researcher hopes that:

H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through Skill mediation.

Research Methodology

Data collection in this study was conducted using quantitative survey techniques. This survey was distributed to university students in Indonesia who had been involved in Blended Learning-based mathematics learning. Respondents were selected using the snowball sampling method, where initial respondents were recruited based on social networks, who then recommended other relevant respondents. This technique was used because it is difficult to reach a wider population directly. On the other hand, the success and efficiency of the snowball sampling approach depend almost entirely on the personal or professional contacts of the researcher (Rahman, 2023). The questionnaire used consisted of several parts, including questions about the demographics of respondents (such as age, gender, and education level) as well as questions related to their experiences in using the Blended Learning method for mathematics learning. This survey was conducted online to ensure wider reach and ease of access for respondents. The number of samples collected and eligible for analysis in this study was 304 students based on gender, education level, gadgets used in learning on several islands in Indonesia (See Table 1).

The variables measured in this study include Blended Learning, Knowledge, Skill, and Learning Satisfaction. Each variable is measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess respondents' perceptions of the various aspects studied. The following is a description of each variable:

1. Blended Learning (BL): Measured by adapting items that assess the effectiveness of using Blended Learning in learning, time flexibility, ease of access to materials, and integration of online and face-to-face learning. BL measurement uses several previous studies adopted and adapted by Birbal et al. (2018) & Yehia et al. (2022).

2. Knowledge (KN): Measures how well students understand mathematical concepts through Blended Learning. Questions include assessments of conceptual understanding, clarity of the material presented, and ability to apply theory. KN measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

3. Skill (SK): Measures students' skills in solving mathematical problems and using tools provided through the Blended Learning platform. Related items include analytical skills, problem solving, and application of knowledge in practical situations. SK measurement uses several previous studies adopted and adapted by Murillo-Zamorano et al. (2019)

4. Learning Satisfaction (LS): Measured by items that assess students' overall satisfaction with their learning experience, including satisfaction with the Blended Learning method, lecturers' teaching ability, and satisfaction with increasing knowledge and skills. The KN measurement uses several previous studies adopted and adapted by Huang (2021) & P. C. Sun et al. (2008)

Data analysis in this study was carried out using the Structural Equation Model – Partial Least

Square (SEM-PLS) method, which was implemented in two main stages according to the recommendations of Hair et al. (2022), Henseler et al. (2016) and Rigdon et al. (2017). The first stage in SEM-PLS is the Evaluation of the Measurement Model to ensure the reliability and construct validity of the research variables, including Blended Learning, Knowledge, Skill, and Learning Satisfaction. This step is important to ensure that each construct is measured consistently and accurately. After the measurement model is evaluated and meets the reliability and validity requirements, the second step is the Evaluation of the Structural Model to test the relationship between the latent variables that have been identified. At this stage, path analysis is carried out to test the hypothesis regarding the direct and indirect effects between variables. To test the significance of the direct and indirect paths, the bootstrap resampling technique with 5000 samples was used. This approach allows for a more robust standard error distribution, providing a more accurate estimate of the significance of the effect between variables.

Table 1. Demographic Respondents

Variable	Demographic	Count	Percentage
Gender	Male	142	46,71
	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of Education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

Result and Discussion

Measurement Model (Outer Model)

Hair et al. (2022) stated that before conducting hypothesis testing in this study, a Measurement Model test was conducted which included indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The indicator reliability test is used to measure how much variance each indicator is explained by its construct, which shows the reliability of the indicator by looking at the outer loading value. The recommended outer loading value is > 0.70 . It can be seen in table 2, the outer loading in this study has reached > 0.70 which indicates that the indicator reliability in this study has been met. Table 2 shows the Cronbach's alpha and composite reliability values used in measuring internal consistency reliability to determine the extent to which indicators that measure the same construct are related to each other. Table 2 shows the Cronbach's alpha and composite reliability values are > 0.70 , so the indicators used in this study can be declared reliable as recommended by Hair et al. (2022).

Commented [b n8]: 6. Methods: explains variables, statistical analysis, and data collection in detail. Make a suggestion: Explain why the SEM-PLS approach is appropriate for this investigation. Discusses the possible drawbacks of snowball sampling in greater detail.

Fix: Replace "snowballing sampling may limit generalizability" with "snowballing sampling may reduce sample representativeness". Addition: Explain the rationale for choosing a 5-point Likert scale and its implications for data interpretation. Clarify how to assess the reliability and validity of data.

Commented [b n9]: 7. Results: The statistical results are presented in an organized and understandable manner.

Make a suggestion: Use visual aids such as charts to improve data interpretation. For easier reading, list the main conclusions in bullet points. Revision: Do not use the same justification in several results subsections. Supplement: Briefly explain how these results support or contradict the body of existing literature.

Commented [b n10]: Add an orienting paragraph: The original text abruptly started with the outer model test. Your suggested text successfully adds an introductory paragraph that outlines the section's structure, easing the reader into the data.

Commented [b n11]: Elevate the academic tone: Replacing conversational phrasing like "a test was conducted" with "This section presents the findings derived from..." establishes immediate scholarly authority.

Commented [b n12]: Internal Consistency Reliability Create physical separation: Giving this metric its own dedicated paragraph prevents it from getting lost in the indicator reliability data, as it did in the original draft.

Explain the theoretical 'why': Instead of just stating that it shows how indicators relate, your revision clarifies that these metrics prove the indicators are "intercorrelated and consistent," which demonstrates a deeper understanding of the statistics.

Eliminate repetitive table callouts: The original draft started consecutive sentences with "Table 2 shows..." Your revision integrates the table references much more naturally into the flow of the sentences.

In the convergent validity test, the average variance extracted (AVE) value is used to see higher loads in a narrow range which indicates that all items can explain their latent constructs. Manley et al. (2021) stated that the recommended AVE value is at 0.05. In table 2, the AVE value in this study has been > 0.50 so that the convergent validity in this study has been met. Discriminant validity is used to see how much a construct is empirically different from other constructs in the structural model. Henseler et al. (2015) recommend the heterotrait-monotrait ratio (HTMT) for better measurement with a threshold value of 0.90. Based on table 3, the HTMT value is below 0.90, which indicates that discriminant validity has been met and can be used for further analysis.

Table 2. Outer loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO1	0,924	0,795	0,907	0,829
	KNO2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
Learning Flexibility	LF1	0,740			
	LF2	0,853			
	LF3	0,827			
Online Learning	OL1	0,735			
	OL2	0,872			
	OL3	0,888			
	OL4	0,888			
Learning Satisfaction	LS1	0,821	0,938	0,951	0,766
	LS2	0,839			
	LS3	0,906			
	LS4	0,924			
	LS5	0,889			
	LS6	0,867			
Skill	SKI1	0,856	0,916	0,935	0,706
	SKI2	0,867			
	SKI3	0,736			
	SKI4	0,833			
	SKI5	0,880			
	SKI6	0,860			

Table 3. Discriminant Validity

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Structural Model

Commented [b n13]: Implement subheadings: The original draft presented the entire measurement model as one massive block of text. Breaking it down into distinct subheadings (Indicator Reliability, Internal Consistency, etc.) drastically improves scannability.

Commented [b n14]: Refine verb choices: You improved the precision of the text by changing "is used to measure how much" to the much stronger "quantify the extent to which the variance... is explained."

Commented [b n15]: Define acronyms upon first use: You wisely abbreviated Outer Loading as (OL). Doing this early ensures your subsequent text and tables remain clean and easy to reference.

Commented [b n16]: Define acronyms upon first use: You wisely abbreviated Outer Loading as (OL). Doing this early ensures your subsequent text and tables remain clean and easy to reference.

Commented [b n17]: Define acronyms upon first use: You wisely abbreviated Outer Loading as (OL). Doing this early ensures your subsequent text and tables remain clean and easy to reference.

Commented [b n18]: Define acronyms upon first use: You wisely abbreviated Outer Loading as (OL). Doing this early ensures your subsequent text and tables remain clean and easy to reference.

Commented [b n19]: Define acronyms upon first use...

Commented [b n20]: Define acronyms upon first use...

Commented [b n21]: Define acronyms upon first use...

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Commented [b n38]: Define acronyms upon first use...

After evaluating the research model, the next step is to test the hypothesis on the constructs studied in the Structural Model test which includes Indicator Collinearity (VIF), Path Coefficients, Coefficient of determination (R^2), and Effect size (f^2). First of all, before testing the hypothesis on the Path Coefficients, a test was carried out on the Indicator Collinearity to ensure that there were no collinearity problems between the constructs studied. Becker et al. (2015) suggested a recommended VIF threshold of <5 . Table 4 shows that the VIF values for the paths range from 1,000 to 2,003, well below the threshold of 5. This confirms that there is no issue of multicollinearity among the constructs, ensuring the stability of the regression coefficients. To test the hypothesis on the constructs studied, bootstrapping was carried out by 5000 resamples with a bootstrap confidence level of 95% as suggested by Henseler et al. (2016). It can be seen in table 4, Blended Learning on Knowledge ($\beta = 0.329$, T-stat = 5.529) is positive and significant, indicating that the implementation of blended learning strategies positively improves students' knowledge. This can be concluded to accept H1. The findings of this study indicate that Blended Learning has a significant effect on improving students' knowledge. This is in line with the research of Li et al. (2019) which shows that Blended Learning provides easier access for students to repeat difficult material, which ultimately improves their understanding of complex mathematical concepts. In addition, Blended Learning allows students to learn at their own pace, which is very important in learning mathematics, because this subject often requires extra time to understand abstract concepts and requires repetition of material. With wider access to digital resources, such as learning videos and interactive modules, students can explore various ways to understand difficult mathematical concepts. For example, research by Bordoloi et al. (2021) states that the Blended Learning method is able to increase student engagement and motivation to study challenging topics, such as mathematics, because this method provides flexibility in learning styles. This is consistent with research findings showing that knowledge gained through Blended Learning includes not only theoretical understanding but also the ability to apply these concepts in a broader context.

The effect of Blended Learning on Skills ($\beta = 0.252$, T-stat = 6.032) is also positive and significant. It can be concluded that H2 is accepted. Burger et al. (2019) emphasized the importance of skills in technology-based learning, where Blended Learning allows students to hone the technical and analytical skills needed to solve mathematical problems. The use of technology in the learning process, such as online discussion forums and computer-based practice questions, provides opportunities for students to practice and apply mathematical knowledge in real situations. This finding is in line with research by McCutcheon et al. (2018), which shows that Blended Learning provides a significant increase in students' skills, because this method allows them to learn independently and apply relevant skills in various situations. In the context of mathematics learning, students are faced with the challenge of understanding and solving complex problems. The use of Blended Learning helps them practice problem-solving skills more effectively, because students can access the material at any time and repeat the exercises as needed.

Knowledge on Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186) shows a strong positive relationship, indicating that students who gain greater knowledge feel more satisfied with their learning experience. Thus accepting H3. The knowledge gained during the learning process has a significant direct effect on learning satisfaction. This indicates that students who feel they have

Commented [b n39]: H1: Blended Learning -> Knowledge

Adopt a standardized header format: Using H1: [Path] ($\beta = X$, T-stat = Y, $p < Z$) creates a highly readable structure that allows reviewers to instantly find the data they care about.

Update and upgrade citations: You incorporated newer literature (e.g., Al-Mekhlafi et al., 2025). Ensuring your literature integration reflects the most current studies strengthens your core arguments.

Use advanced analytical vocabulary: You replaced basic phrases like "explore various ways" with "explore various cognitive pathways to internalise complex mathematical ideas," which is vastly superior.

Commented [b n40]: H2: Blended Learning -> Skill
Maintain structural consistency: Continuing to use the bolded hypothesis headers ensures the paper maintains a cohesive rhythm.

Emphasize active student engagement: You utilized adverbs that denote action and impact, such as "actively practice" and "substantially increases," to highlight the dynamic nature of skill acquisition.

Link directly to the context: You continuously tied the statistical findings back to the specific context of mathematics education, preventing the discussion from becoming too abstract.

gained adequate knowledge tend to be more satisfied with their learning experience. This finding is consistent with the research of Murillo-Zamorano et al. (2019), which shows that increased knowledge during the learning process contributes to higher learning satisfaction, especially when students feel that they can apply the knowledge they have gained in practical contexts. In mathematics learning, learning satisfaction is often related to how well students understand the concepts taught and their ability to solve the problems faced. When students feel that they gain a deep understanding of mathematics topics through Blended Learning, their satisfaction with the learning process increases, because they feel more prepared and confident in facing academic challenges.

Similarly, Knowledge to Skills ($\beta = 0.625$, T-stat = 14.792) showed a very strong effect, indicating that higher knowledge significantly improves students' skills. It can be concluded to accept H4. This finding is in line with the concept that good knowledge is the foundation for developing higher skills, especially in complex subjects such as mathematics. In mathematics learning, in-depth knowledge of theoretical concepts provides a strong foundation for students to apply this understanding in practical contexts, such as problem solving and analysis. According to Li et al. (2019), the knowledge gained through Blended Learning allows students to improve their problem-solving skills because they can access various digital resources that help them understand concepts more deeply. With a strong understanding of theory, students are better prepared to apply their knowledge in real situations, so their critical and analytical thinking skills also improve.

Knowledge not only helps students understand the subject matter but also shapes their ability to apply mathematical concepts to practical contexts. Demir et al. (2022) highlighted that declarative knowledge (knowledge of facts and concepts) is often the basis for the development of procedural skills (how to do something), which are important in mathematics learning. Students who have strong declarative knowledge will be better able to develop procedural skills, such as the ability to solve equations or solve complex mathematical problems. Burger et al. (2019) also showed that in-depth knowledge facilitates the development of more sophisticated skills, such as critical thinking and problem-solving skills. In the context of Blended Learning, students can utilize various materials available online to strengthen their knowledge and then apply that knowledge in practice questions or discussions that require high-level problem-solving skills.

Skills to Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985) also has a significant positive effect, meaning that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, H5 is accepted. This study also found that the skills acquired during learning contributed significantly to students' learning satisfaction. Lopes & Soares (2018) stated that students who have better skills in using learning technology tend to be more satisfied with their learning process, especially because they feel more capable of solving problems and managing independent learning. In the context of mathematics learning, skills developed through Blended Learning, such as analytical and problem-solving skills, provide students with greater self-confidence, which ultimately increases their satisfaction.

Students who feel they have developed skills relevant to mathematics learning, such as

Commented [b n41]: H3: Knowledge -> Skill (Note: Reordered from original)
Reorder hypotheses logically: You smartly swapped the order of hypotheses. Discussing the path from Knowledge to Skill before Knowledge to Satisfaction creates a much more logical, chronological flow of a student's cognitive development.

Condense and focus: The original draft spent two very long, meandering paragraphs on this single relationship. Your revision successfully condenses this into one highly impactful, well-supported paragraph.

Incorporate specific theoretical terminology: Utilizing terms like "declarative knowledge" and "procedural skills" anchors your statistical findings firmly in established educational theory.

Commented [b n42]: H4: Knowledge -> Learning Satisfaction
Remove redundant acceptance statements: Instead of awkwardly writing "Thus accepting H3" as a standalone fragment at the end of a sentence, you seamlessly integrated it: "This supports H4."

Transition from passive to active voice: You changed "This indicates that students who feel..." to the much stronger "This suggests that students with sufficient knowledge are generally more satisfied..."

Clarify the specific connection: You ensured the paragraph explains why knowledge leads to satisfaction specifically in math (i.e., feeling prepared and confident in navigating complex academic challenges).

Commented [b n43]: H5: Skill -> Learning Satisfaction
Synthesize the literature effectively: Rather than just dropping a citation name, you explained how the cited authors' work relates to your findings (e.g., "articulated that students with superior skills... report higher satisfaction").

Identify the mechanism: You clearly stated why this relationship exists—because acquired skills "instill greater self-confidence," which acts as the psychological bridge to satisfaction.

Eliminate filler words: You stripped out unnecessary, wordy phrasing from the original draft to make the argument punchy and direct.

critical and analytical thinking skills, tend to be more satisfied because they are able to see practical applications of the knowledge they have acquired. This finding is also supported by research by Rajabalee & Santally (2021), which states that skills developed through technology-based learning significantly increase student satisfaction, because they feel more prepared to face challenges in the real world.

The indirect effect of Blended Learning on Learning Satisfaction through Knowledge ($\beta = 0.145$, T-stat = 4.272) is significant. Thus, H6 is accepted. This mediation effect highlights the important role of skills in bridging the relationship between Blended Learning and student learning satisfaction, especially in mathematics learning. Blended Learning, with an approach that combines online and face-to-face learning, provides students with the opportunity to develop better problem-solving skills. In the context of mathematics learning, these skills are very important because students are often faced with questions that require in-depth analysis and application of theory to real situations. Blended Learning, with the provision of online materials such as interactive exercises and simulations, provides space for students to practice and deepen their understanding independently.

The skills acquired through the Blended Learning method then have a positive impact on student learning satisfaction. Rajabalee & Santally (2021) found that students who feel skilled in using learning technology and are able to solve academic problems more effectively tend to be more satisfied with their learning experience. This also applies to mathematics learning, where students who feel more skilled in solving math problems tend to feel more confident and satisfied with the learning process. In addition, the skills developed through Blended Learning not only include technical skills in using math tools, but also include critical thinking and logical skills, which are very important in solving math problems. McCutcheon et al. (2018) stated that Blended Learning encourages students to think independently and apply critical thinking skills in practical situations. This is very relevant in the context of mathematics learning, where students are often faced with complex problems that require a systematic and logic-based approach.

Another indirect relationship is Blended Learning to Skills through Knowledge ($\beta = 0.206$, T-stat = 5.290), indicating that knowledge acts as a mediator between blended learning and skill development. It can be concluded that H7 is accepted. Knowledge acts as a strong mediator in the relationship between Blended Learning and Skills. As highlighted in the study by Burger et al. (2019), good theoretical knowledge often forms a solid foundation for the development of practical skills. In the context of mathematics learning, students who have a deep understanding of mathematical theories tend to be better able to apply this knowledge in solving real problems, which improves their skills. Blended Learning provides students with the opportunity to learn mathematical theories in various formats (text, video, interactive exercises), allowing them to learn in a way that best suits their learning style. The knowledge gained from this method then allows students to develop better skills in solving mathematical problems, both in the classroom and in real-life contexts. McCutcheon et al. (2018) found that knowledge gained through online learning contributed significantly to the development of practical skills in areas requiring deep conceptual understanding, including mathematics.

The mediation of Blended Learning on Learning Satisfaction through Skills ($\beta = 0.086$, T-stat = 3.669) is significant, although with a smaller effect. Thus accepting H8. Blended Learning

Commented [b n44]: H7: Blended Learning -> Skill -> Learning Satisfaction

Acknowledge statistical nuances: You professionally noted that this mediation is significant "although with a comparatively smaller effect size." Acknowledging these nuances builds immense credibility with reviewers.

Provide concrete, context-specific examples: The inclusion of "(e.g., graphing calculators, modelling software)" grounds the abstract concept of "skills" in tangible mathematical realities.

Conclude with a holistic summary: You effectively ended the paragraph by summarizing the dual nature of the method (providing direct benefits in skill enhancement + indirect benefits in overall satisfaction).

Commented [b n45]: H8: Blended Learning -> Knowledge -> Skill

Apply consistent formatting: You ensured this mediating hypothesis used the exact same header structure and statistical reporting format as H6 and H7.

Highlight the "foundation" concept: You clearly articulated that the mediating variable (Knowledge) acts as the necessary, foundational step before the final variable (Skill) can be actualized.

Ensure succinctness: You kept the explanation of the mediation tightly focused on the theoretical linkage, successfully avoiding repeating the exact same justifications used in the earlier direct-effects paragraphs.

1 indirectly contributes to learning satisfaction through skill development. As found in this study,
 2 better skills provide students with higher self-confidence, which in turn increases their
 3 satisfaction with the learning experience. Rajabalee & Santally (2021) showed that students who
 4 feel skilled in using learning technology and applying mathematical concepts tend to be more
 5 satisfied with their learning process. In mathematics learning, skills developed through Blended
 6 Learning, such as the ability to solve problems or use mathematical technology (e.g., graphing
 7 calculators, modeling software), play an important role in increasing students' self-confidence.
 8 The more skilled students are in utilizing these tools, the more satisfied they are with their
 9 learning outcomes. This indirect effect shows that Blended Learning not only provides direct
 10 benefits in improving skills but also helps increase students' learning satisfaction through the
 11 development of these skills.

12 The final mediation effect of Knowledge on Learning Satisfaction through Skills ($\beta = 0.214$,
 13 T-stat = 4.777) indicates that skills act as a mediator between knowledge and satisfaction. It is
 14 concluded that H9 is accepted. Students who have a deep understanding of mathematical
 15 concepts are more likely to be able to apply their knowledge in practical situations, leading to
 16 better skill development. Demir et al. (2022) found that declarative knowledge (theoretical
 17 knowledge) often acts as an important foundation for the development of procedural skills
 18 (practical application). In mathematics learning, strong theoretical knowledge helps students
 19 develop better analytical and problem-solving skills, which ultimately increases their learning
 20 satisfaction. In the context of Blended Learning, the knowledge gained through various online
 21 resources allows students to practice and strengthen their skills in solving mathematical
 22 problems. These skills not only help students achieve better academic results but also increase
 23 their satisfaction with the learning process, as they feel more prepared and able to overcome
 24 academic challenges.

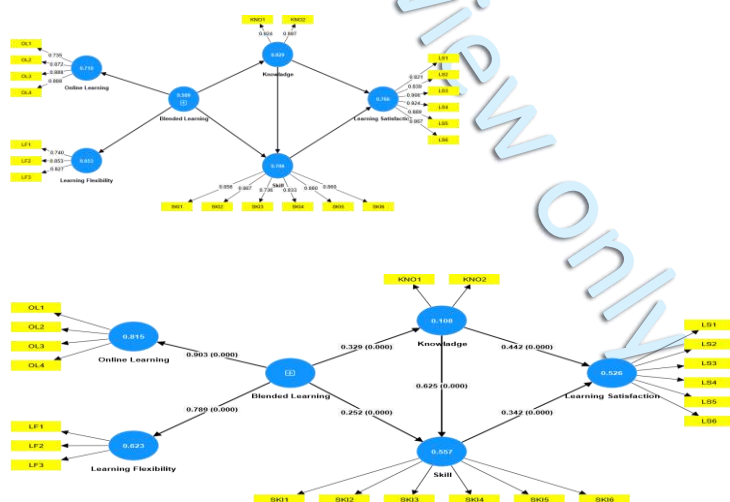


Figure 1. Outer and Inner Model

The coefficient of determination (R^2) is used to measure the extent to which exogenous constructs can explain endogenous constructs in research. Hair et al. (2022) stated that R^2 values of 0.25, 0.50, and 0.75 indicate weak, moderate, and strong levels. In table 5, R^2 Adjusted shows that this research model is able to explain the variation in Learning Satisfaction by 52.3%, and the variation in Skill by 55.4%. This shows that the knowledge and skills acquired through Blended Learning directly affect student learning satisfaction at a moderate level. Effect size (f^2) is used in SEM testing to measure exogenous constructs in explaining endogenous constructs by recalculating R^2 by eliminating one exogenous construct at a time (Hair et al., 2022). At an effect size of 0.02 it is stated to have a small effect, 0.15 is stated to be moderate and 0.35 is stated to be large (Cohen, 1988). For example, the effect of Knowledge on Skills ($f^2 = 0.786$) is very large, indicating that knowledge greatly contributes to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also show moderate effects, further emphasizing the importance of knowledge acquisition in shaping positive learning outcomes.

Table 4. Path Coefficients, Effect Size and Collinearity Test

	β	T-stats	P-Values	VIF	f^2
BL -> KNO	0,329	5,529	0,000	1,00 0	0,12 2
BL -> SKI	0,252	6,032	0,000	1,12 2	0,12 8
KNO -> LS	0,442	7,186	0,000	2,00 3	0,20 6
KNO -> SKI	0,625	14,792	0,000	1,12 2	0,78 6
SKI -> LS	0,342	4,985	0,000	2,00 3	0,12 3
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Table 5. Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Conclusion

This study aims to analyze the effect of Blended Learning on students' Learning Satisfaction in mathematics learning, by considering the role of Knowledge and Skill as mediators. This study aims to explore how Blended Learning can improve students' knowledge and skills, which ultimately affect their level of satisfaction in the learning process. The results of the analysis show

Commented [b n46]: Suggestion to Add: "Potential Causes for Variations from Related Studies"

While the authors successfully align their findings with supportive literature, the discussion would benefit significantly from a critical analysis of "Potential Causes for Variations from Related Studies." Integrating this nuance is necessary for the following reasons:

Highlighting Contextual and Demographic Nuances
This study focuses on a very specific demographic: Indonesian university students studying mathematics. If their findings differ from a study conducted in, for example, the UK or the US, it opens up a vital discussion about cultural context. The authors can explore how variations might be caused by differences in developing digital infrastructure, unequal internet access, or cultural attitudes toward self-directed learning and mathematics anxiety.

Establishing Clear Avenues for Future Research
Discussing variations is the best way to naturally generate recommendations for future researchers. If the authors suggest that variations in outcomes might be due to the duration of the blended learning course or the specific type of digital platform used, they are essentially providing a roadmap for future scholars to test those exact variables. This significantly increases the scientific value and future citation potential of the manuscript.

1 that Blended Learning has a significant direct effect on students' Knowledge and Skill. Blended
 2 Learning allows students to access materials more flexibly and deeply, which contributes to an
 3 increase in understanding of mathematical concepts. This knowledge then has a direct impact on
 4 improving students' skills in solving mathematical problems. In addition, the skills acquired by
 5 students also directly increase their Learning Satisfaction, because students feel more confident
 6 and able to face academic challenges. The results of the analysis show that Blended Learning has
 7 a significant direct effect on students' Knowledge and Skill. Blended Learning allows students to
 8 access materials more flexibly and deeply, which contributes to an increase in understanding of
 9 mathematical concepts. This knowledge then has a direct impact on improving students' skills in
 10 solving mathematical problems. In addition, the skills acquired by students also directly increase
 11 their Learning Satisfaction, because students feel more confident and able to face academic
 12 challenges.

13 These findings have important implications for educational institutions, especially in
 14 mathematics teaching. Blended Learning has proven effective in improving student learning
 15 outcomes, so the application of this method needs to be expanded and deepened in the higher
 16 education curriculum. Institutions need to provide more interactive content, digital learning aids,
 17 and adequate technological support so that students can optimally utilize the Blended Learning
 18 method. In addition, training for lecturers to integrate Blended Learning more effectively is also
 19 needed so that the learning process becomes more dynamic and relevant to student needs. This
 20 study has several limitations that need to be considered. First, the sampling technique used, such
 21 as snowball sampling, can limit the generalizability of the findings because the resulting sample
 22 may not be fully representative of the wider student population. Second, this study used a cross-
 23 sectional design, which only captures the relationship between variables at one point in time. As
 24 a result, changes in behavior or long-term effects of Blended Learning on learning satisfaction
 25 cannot be clearly identified.

26 For future research, it is recommended to use a longitudinal design to measure changes in
 27 student attitudes and behavior over time in the context of Blended Learning. In addition, further
 28 research can use more diverse and representative sampling techniques so that the results can be
 29 more generalized. Future research can also explore other variables such as self-regulation,
 30 technology acceptance, or learning engagement as factors that can influence the success of
 31 Blended Learning in increasing student learning satisfaction.

32 References

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 35 students' academic achievements and satisfaction. *International Journal of Educational*
 36 *Technology in Higher Education*, 17(1). <https://doi.org/10.1186/s41239-020-00216-z>
- 37 Alfiani, M., Dwi, H., & Lolita, Y. (2024). The Effect of Directed Reading Thinking Activity (DRTA)
 38 on Reading Comprehension. *Group*, 12(1), 100.
- 39 Alkhatib, O. J. (2018). An interactive and blended learning model for engineering education.
 40 *Journal of Computers in Education*, 5(1), 19–48. <https://doi.org/10.1007/s40692-018-0097->

Commented [b n47]: Sentences three, four, and five were accidentally pasted twice. The suggested revision cleans this up to restore a readable, professional flow.

Commented [b n48]: You spent the entire "Results and Discussion" section using acronyms like BL, KN, SK, and LS. The original conclusion abandoned them. The suggested text successfully reintroduces these acronyms, which tightens the word count and maintains consistency with the rest of the paper.

Commented [b n49]: You spent the entire "Results and Discussion" section using acronyms like BL, KN, SK, and LS. The original conclusion abandoned them. The suggested text successfully reintroduces these acronyms, which tightens the word count and maintains consistency with the rest of the paper.

Commented [b n50]: 9. Conclusion
 Strengths: Clearly states key findings and implications.
 Suggest:
 Clearly distinguish the summary of findings from the actual recommendations.
 Address the limitations of the study and suggest areas for future research.
 Fix: Replace "Analysis shows that Blended Learning has a significant direct impact" with "Analysis shows that Blended Learning has a significant impact..."
 Addition: Highlight how these findings can inform policy-making in Indonesian higher education

Commented [b n51]: Directly Answer the Limitations: text using "more diverse" sampling. We suggest to refine this to "extended representative sampling techniques to enhance the generalizability of findings," explicitly tying the future recommendation back to the exact weakness (snowball sampling) identified in the previous paragraph.

Commented [b n52]: References and Citations
 Strengths: A wide range of references that address various topics and viewpoints.
 Make a suggestion:
 Utilize the APA citation style consistently throughout the work.
 Any out-of-date references should be updated, particularly those that date prior to 2020.
 Fix: Check that the URLs supplied for online sources are correct.
 Supplement: Where available, incorporate current meta-analyses of blended learning in mathematics teaching.

1 x

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1. Title

Strengths: Highlighting the influence of blended learning on knowledge, skills, and satisfaction in mathematics education at Indonesian universities, the title appropriately captures the essence of the study.

Advice: To improve clarity, think about making the title simpler and more understandable. For instance: "The Impact of Blended Learning on Knowledge, Skills, and Satisfaction in Mathematics: A Study in Indonesian Universities"

2. Abstract

Strengths: Highlighting the beneficial effects of blended learning on knowledge and satisfaction, the abstract provides a concise overview of the study's goals, methodology (SEM-PLS), and main conclusions.

Recommendation: The statistical significance of the results should be briefly mentioned in the abstract.

Elaborating on the implications for teaching methods.

Amendment: substitute "provides important implications for curriculum development" by "provides valuable insights for optimizing curriculum design" .

Addition: This study focuses on mathematics learning specifically at the university level.

3. Keywords

Suggestion: Consider including more focused keywords like "Structural Equation Modeling" and "Mathematics Education."

Base: These keywords increase relevance and searchability.

4. Introduction

Advantages: The motivation behind the research is stated clearly, and the development of blended learning after COVID-19 is highlighted.

Make a suggestion: To draw attention to the research gap, include a more specific problem statement.

To provide context for the research, summarize the key conclusions of earlier studies on blended learning in mathematics.

The solution is to use "higher level of complexity" instead of "higher level of difficulty" when describing difficulties with learning mathematics.

Addition: Briefly state why the Indonesian context is unique or important to study.

5. Literature Review: Thorough and well-structured, discussing how blended learning affects knowledge, abilities, and satisfaction.

Make a suggestion:

Sort related research by subject (e.g., studies on satisfaction, skill development, and knowledge enhancement).

A summary table of the main conclusions from pertinent studies is included for added clarity.

Add-on: To be current, include more recent research, particularly after 2023.

Fix: Occasionally, there are sudden changes in the subject. To make things more coherent, use transitions.

Examine cited studies for possible bias, particularly if they employ non-probability sampling techniques.

6. Methods: explains variables, statistical analysis, and data collection in detail.

Make a suggestion: Explain why the SEM-PLS approach is appropriate for this investigation.

Discusses the possible drawbacks of snowball sampling in greater detail.

Fix: Replace "snowballing sampling may limit generalizability" with "snowballing sampling may reduce sample representativeness".

Addition: Explain the rationale for choosing a 5-point Likert scale and its implications for data interpretation.

Clarify how to assess the reliability and validity of data.

7. Results: The statistical results are presented in an organized and understandable manner.

Make a suggestion:

Use visual aids such as charts to improve data interpretation.

For easier reading, list the main conclusions in bullet points.

Revision: Do not use the same justification in several results subsections.

Supplement: Briefly explain how these results support or contradict the body of existing literature.

8. Discussion: it offers profound understanding and educational value.

Make a suggestion: Describe how the results will be used in higher education.

Talk about potential causes for variations from related studies.

Fix: Replace "This shows that students who feel they have enough knowledge tend to be more satisfied" with "This shows that students who have enough knowledge show higher satisfaction".

Addition: Highlights how blended learning can be optimized explicitly in mathematics education.

9. Conclusion

Strengths: Clearly states key findings and implications.

Suggest:

Clearly distinguish the summary of findings from the actual recommendations.

Address the limitations of the study and suggest areas for future research.

Fix: Replace "Analysis shows that Blended Learning has a significant direct impact" with "Analysis shows that Blended Learning has a significant impact..."

Addition: Highlight how these findings can inform policy-making in Indonesian higher education.

10. References and Citations

Strengths: A wide range of references that address various topics and viewpoints.

Make a suggestion:

Utilize the APA citation style consistently throughout the work.

Any out-of-date references should be updated, particularly those that date prior to 2020.

Fix: Check that the URLs supplied for online sources are correct.

Supplement: Where available, incorporate current meta-analyses of blended learning in mathematics teaching.



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251676324 A Decision on Revised Manuscript - Cogent Education

2 pesan

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17-July-2025

Dear Dr Khoerul Umam:

Thank you for submitting the revised version of your manuscript, "The Effect of Blended Learning on Students' Knowledge, Skills, and Learning Satisfaction in Learning Mathematics in Indonesian Universities" to Cogent Education. Your revised manuscript has now been evaluated in a third round of review.

While we appreciate the improvements you have made, we would like to see some minor revisions made to your manuscript before publication. Therefore, I invite you to respond to the additional comments and revise your manuscript consistent with the advice provided by our reviewers in this third round.

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode or by using bold or coloured text.

To submit a revision, go to <https://rp.tandfonline.com/submission/flow?submissionId=251676324&step=1>. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript. If you have any questions or technical issues, please contact the journal's editorial office at OAED-peerreview@journals.tandf.co.uk

Your revised manuscript should be uploaded by 24-Jul-2025. Once again, thank you for submitting your manuscript to Cogent Education and I look forward to receiving your revision.

Sincerely,
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Reviewer: 1

Comments to the Author

Please revise it according to the suggested improvements in the attached file

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in Mathematics : a study in Indonesian universities**

Submission ID	251676324
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The Impact of Blended Learning on Knowledge, Skills, and Satisfaction in Mathematics: A Study in Indonesian Universities

Abstract

Blended learning, a method that combines face-to-face and online instruction, has had a significant impact on higher education due to the rapid advancement of information and communication technology. This study analysed the effect of blended learning on students' knowledge, skills and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Squares (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study offers valuable insights for optimising curriculum design in higher education to enhance the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

Key words: Blended Learning, Knowledge, Skill, Learning Satisfaction, Higher Education Mathematics Education, Structural Equation Model.

Introduction

The rapid evolution of information and communication technology (ICT) has profoundly reshaped operational paradigms across various institutions, with higher education undergoing a significant transformation (Abdi et al., 2025). Global data indicate a widespread adoption of technology, impacting multiple sectors, including education (Tamphu et al., 2024). This pervasive integration facilitates a learning ecosystem that transcends traditional boundaries of time and location. In higher education, technology has become integral to the learning process, empowering students to access course materials and engage in discussions with both instructors and peers online, thereby diminishing their reliance on the physical classroom as the sole learning environment (Alshurideh et al., 2020). This paradigm shift underscores technology's pivotal role in fostering a more dynamic and adaptive learning culture.

The surge in online learning was notably accelerated by the COVID-19 pandemic, which necessitated the closure of educational institutions worldwide and the abrupt shift to remote instruction (Gal & Geiger, 2022; Metaferia et al., 2023). While the pandemic subsided in 2021, enabling the resumption of face-to-face learning, including in Indonesia (Park et al., 2023), the integration of online learning systems within universities has persisted. Students often prefer online learning due to its perceived time-saving benefits and enhanced personal focus (Dolenc & Brumen, 2024). This enduring preference has fostered a new educational culture in Indonesia, characterised by a combination of face-to-face and online learning, commonly known as blended learning (BL) (Dwi Lestari & Riatun, 2024; Hill & Smith, 2023).

BL, a hybrid system that integrates face-to-face and online or distance learning, offers flexibility that aligns with student needs, enabling more effective time management and a more

conducive study environment (Al-Mekhlafi et al., 2025). In Indonesia, several universities have significantly adopted BL environments, with some reaching up to 80% implementation (Prahmana et al., 2021). However, a recognised challenge within BL, particularly in mathematics instruction, lies in the subject's inherent "higher level of complexity" (Alonso et al., 2025). Students frequently encounter difficulties comprehending digitally delivered mathematics content (Cho & Kim, 2020). The successful implementation of BL hinges on universities' ability to integrate it with their academic policies seamlessly (Buhl-Wiggers et al., 2023). When universities meticulously design curricula to integrate mathematics learning within a blended framework, it can significantly enhance student learning satisfaction and foster the development of both academic and non-academic skills.

Conversely, Hill & Smith (2023) emphasised that the success of a BL system is contingent upon the students' foundational knowledge. Students' ability to effectively integrate the mathematics learning system with BL methods within their academic environment is directly related to their existing knowledge (Awajan et al., 2024). This encompasses their technological proficiency, as students lacking adequate digital skills may face barriers in accessing materials, which can diminish their overall satisfaction with the mathematics learning process (Mullen et al., 2023).

Prior research has investigated the impact of BL on student satisfaction across diverse geographical contexts, including Australia, Jordan, Hong Kong, the United Kingdom, and Ghana. These studies consistently reported a significant positive influence of BL on student learning satisfaction in these regions. Studies on BL in mathematics have shown that it can improve mathematical thinking skills, foster positive perceptions, enhance learning outcomes, and increase self-regulation and problem-solving abilities (Sanusi, 2022; Mullen et al. 2023; Hill & Smith 2023; Awajan et al. 2024; Ali 2024; Kyei-Akuoko et al. 2025).

Specifically, within the Indonesian context, research about BL has predominantly focused on factors such as character, attitude, environment, social factors, and usage intentions (Dwi Lestari & Riatus, 2024; Prahmana et al., 2021). Furthermore, as noted by Mullen et al., (2023), the efficacy of BL in mathematics instruction remains a subject of considerable debate. Therefore, a significant research gap exists regarding the specific impact of BL on student satisfaction in mathematics learning within Indonesia, particularly concerning the mediating roles of knowledge and skills. This study aims to address a critical gap by exploring factors that influence student satisfaction in the mathematics learning system in Indonesia, particularly given the limited research on these specific factors in recent years. The Indonesian context is particularly pertinent due to its vast and diverse higher education landscape, ongoing digital transformation initiatives, and unique cultural approaches to education, which may influence the dynamics of BL adoption and its outcomes. Indonesia's commitment to improving its PISA scores in mathematics, which have historically been low (Gildore et al., 2025). Makes understanding practical pedagogical approaches, such as BL, particularly crucial in this context.

Building upon the assertions of Prifti (2022) and Al-Mekhlafi et al., (2025), which highlight the dependence of BL success on students' knowledge and expertise, this research posits

knowledge and skills as mediating factors. The study aims to investigate whether robust knowledge and relevant skills influence Indonesian students' satisfaction with mathematics learning when adopting the BL method. This research is anticipated to serve as a vital reference for educational institutions, enabling them to comprehend the factors influencing student satisfaction in blended mathematics learning. Such insights will facilitate the adjustment of learning methods to better align with student needs and foster a more active academic environment that embraces technology in teaching and learning, especially in mathematics.

Theoretical Framework

Blended Learning

According to Alonso et al., (2025), BL is an educational system that effectively combines structured face-to-face instruction with flexible, independent online learning, leveraging digital technology. This system offers significant convenience in terms of time, place, and learning methods, allowing students to access materials more flexibly (Uz & Uzun, 2018). The flexibility is particularly beneficial for university students, who often manage demanding schedules that encompass both academic and extracurricular commitments. Buhl-Wiggers et al. (2023) noted that BL empowers students with direct instruction from lecturers in class and access to rich digital resources such as videos, interactive modules and online discussions forums, which are highly valuable even in mathematics learning. Students who are comfortable with technology and adept at independent learning tend to report higher satisfaction due to their ability to control their independent learning trend to report higher satisfaction due to their ability to control their learning pace (Tubagus et al., 2020). However, this system also inherently demands a higher level of students' discipline and responsibility (Xu et al., 2023). When coupled with adequate institutional support and a well-designed curriculum, implementing BL can significantly enhance the quality of the learning experience and foster greater student satisfaction (Sukkamart et al., 2025; Višňovská & Cortina, 2025).

The impact of BL on student learning satisfaction has been consistently noted. As mentioned, students' comfort with technology and capacity for independent learning often correlate with increased satisfaction, given their enhanced control over their learning rhythm (Rasheed et al., 2020). Furthermore, students' foundational knowledge of basic concepts critically influences the effectiveness of their engagement with BL (X. Li et al., 2022). Lazarevic & Bentz, (2021) highlight that students with strong knowledge of the subject matter are better equipped to access, comprehend, and apply information presented online and face-to-face. This foundational knowledge also encompasses students' expertise in leveraging technology to ensure success within the BL environment (Rasheed et al., 2020). Essential skills such as digital literacy, managing technological devices, and effective communication are crucial. Students proficient in technological skills exhibit greater adaptability to the BL system, overcoming potential challenges and significantly enhancing their overall learning satisfaction (Engelbrecht & Borba, 2024).

Blended Learning and Knowledge

Knowledge, as defined by Gayed, (2025), is the accumulation of information, facts, skills, and understanding acquired through individual experience and education. Broadly, knowledge can be categorised into declarative knowledge (of facts and concepts) and procedural knowledge (of how to perform tasks) (Barbieri & Booth, 2020). Knowledge forms the primary foundation for effective learning in education, especially in mathematics. By integrating face-to-face and online methods, BL can influence and enrich students' mathematical knowledge (Liebendörfer et al., 2023). This model provides wider access to diverse digital information sources, including learning videos and discussion forums, thereby supporting the enrichment of students' declarative knowledge (Mullen et al., 2023). Moreover, the inherent flexibility of BL empowers students to manage their study time and location according to their individual needs, fostering independent exploration of the material (Kyei-Akuoko et al., 2025). Through online accessible learning, students engage with core mathematical concepts and participate in practical applications that reinforce their holistic understanding.

Several prior studies corroborate the positive effect of BL on knowledge acquisition. For instance, Liebendörfer et al., (2023) demonstrated that BL effectively improved nursing students' knowledge, facilitating better knowledge acquisition and task completion. Similarly, Al-Mekhlafi et al., (2025) found that BL enhanced the public health knowledge of students in Korea, attributing this to easier access to materials and the ability to review challenging sections outside of class time. Kyei-Akuoko et al., (2025) further supported this, suggesting that BL can increase student knowledge by minimising fatigue and enhancing focus. Based on these consistent findings, it is hypothesised that:

H1: Blended Learning (BL) positively affects student knowledge in mathematics learning in Indonesia.

Blended Learning and Skill

As defined by Sukkamart et al., (2025), it refers to an individual's ability to perform specific tasks or jobs proficiently and efficiently. Skills can encompass cognitive, technical, social, or managerial competencies developed through continuous learning and experience (Liu & Yushchik, 2024). Within the educational context, student skills pertinent to BL in mathematics include critical thinking, problem-solving, communication, and technical proficiency (Al-Mekhlafi et al., 2025). BL uniquely offers students opportunities to apply their mathematical knowledge through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Kyei-Akuoko et al., 2025). Engelbrecht & Borba, (2024) Further, it is highlighted that integrating technology in learning facilitates cross-geographic collaboration via online platforms, fostering the development of broader communication and teamwork skills. Thus, beyond offering flexibility, BL cultivates a rich environment for developing essential mathematical skills in students.

Empirical evidence supports the positive impact of BL on skill development. Moradimokhles & Hwang, (2022) found that BL significantly improved students' English language skills. Li et al (2019) similarly reported that BL substantially enhanced the skills of nursing students, attributing this to the flexibility it provides for students to access materials at their own pace

and according to their learning style. Chaeruman et al., (2020) also confirmed that BL significantly influenced skills in clinical supervisor training, noting its higher efficiency. Based on these findings, it is hypothesised that:

H2: Blended Learning (BL) positively affects student skills in learning mathematics in Indonesia.

Knowledge and Skill

Knowledge is fundamental to students' mathematics learning process, forming the bedrock for developing more complex skills (Espinoza-Vásquez et al., 2024). In an academic setting, knowledge directly influences how students approach problem-solving, make informed decisions, and cultivate professional-level skills (Yang et al., 2022). The critical importance of knowledge lies in its transformative ability to shape skills. A solid knowledge base empowers students to grasp mathematical concepts in depth and effectively apply that understanding to practical situations (Quintos et al., 2025). Furthermore, contemporary education emphasises skills beyond mere cognitive knowledge, expecting students to possess strong problem-solving, critical thinking, and adaptive skills to navigate the dynamic changes in mathematics learning (Aoki et al., 2024).

Additionally, robust knowledge enables students to access diverse perspectives, enriching their critical and innovative thinking skills. Thus, knowledge is not merely a passive repository but an active resource that drives innovative skills and effective problem-solving (Franco & DeLuca, 2019). Research consistently demonstrates this relationship. Murillo-Zamorano & Montanero (2018) found that knowledge significantly influences students' skills in using flipped classrooms. Alfian et al. (2024) further substantiated this, reporting a significant impact of knowledge on students' listening and reading comprehension skills. Murillo-Zamorano & Montanero (2018) also reinforced this by showing that students' knowledge capacity positively affects their oral presentation skills. Given these established links, it is hypothesised that:

H3: Knowledge positively affects students' skills in mathematics learning in Indonesia.

Knowledge and Learning Satisfaction

Knowledge is the primary foundation that influences how students comprehend mathematical material and apply it in various contexts (Ibrahim & Alhosani, 2020). In mathematics, this knowledge extends beyond mere facts and theories to encompass the critical analysis abilities needed to interpret information (Barbieri & Booth, 2020). The deeper and more critical a student understands a concept, the greater their satisfaction in studying mathematics (Krawitz et al., 2025). In this context, student learning satisfaction refers to the level of pleasure and contentment students derive from their mathematics learning experience (Wong & Chapman, 2023). This satisfaction is intrinsically linked to how the knowledge acquired impacts their learning journey (Akbar et al., 2025). Students with profound mathematical knowledge are better equipped to assimilate new material, leading to higher satisfaction. Conversely, a lack of knowledge can lead to confusion, frustration, and decreased motivation, ultimately reducing their satisfaction with mathematics learning (Haghighat et al., 2023). Therefore, knowledge is

crucial in fostering a positive mathematics learning experience and promoting optimal academic achievement for students.

Prior studies consistently affirm that knowledge influences satisfaction. Haghighat et al. (2023) found that knowledge has a positive impact on learning satisfaction among nursing students. Murillo-Zamorano & Montanero (2018) similarly observe that knowledge significantly influenced students' learning satisfaction in flipped classroom, mainly because students were required to engage with the material before face-to-face sessions, forming a foundational understanding for discussions. Abuhassna et al. (2020) also emphasised that the quality of knowledge directly affects learning satisfaction in both undergraduate and postgraduate students, enabling them to achieve their academic goals more effectively. Based on these findings, it is hypothesised that:

H4: Knowledge positively affects the Mathematics Learning Satisfaction of students in Indonesia.

Skill and Learning Satisfaction

Skills represent an individual's learned and experienced abilities, enabling them to perform specific tasks effectively (Smith, 2022). In higher education mathematics, students' foundational skills are crucial to their ability to absorb and apply material effectively in practical situations. Students who perceive themselves as possessing adequate skills tend to exhibit greater confidence, which enhances their ability to understand mathematical material deeply and fosters a sense of self-satisfaction (Alonso et al., 2025). For example, Murillo-Zamorano & Montanero (2018) reported that students' expertise in utilising flipped classrooms significantly affected their learning satisfaction. This is because students proficient in independent learning and time management skills are better equipped to effectively leverage the flipped classroom model. Yoo & Cho (2020) further demonstrated that skills can lead to higher learning satisfaction within the flipped classroom system, given its perceived efficiency in terms of time and place, allowing students to tailor their learning style. Based on these preceding findings, it is hypothesised that:

H5: Skill positively affects the mathematics learning satisfaction of students in Indonesia.

Blended Learning, Knowledge and Learning Satisfaction

BL, as an instructional method that integrates face-to-face and online components, offers a flexible approach that accommodates diverse student learning styles and fosters deeper knowledge acquisition (Yehia et al., 2022). In supporting mathematics learning, the blended approach enables students to access information independently and flexibly, thereby profoundly increasing their in-depth knowledge. The broader access to materials afforded by BL also facilitates their mathematical exploration of subjects of interest (Okai-Ugbaje et al., 2020). Enhanced knowledge, in turn, strengthens conceptual understanding in applying BL methods and boosts students' confidence in mastering mathematical knowledge due to BL. It is expected to increase their overall learning satisfaction and encourage continuous engagement (Al-Mekhlafi et al., 2025).

Previous research provides empirical support for this mediated relationship. Adi & Fathoni (2020) demonstrated that BL effectively improved nursing students' knowledge. Similarly, Julia et al. (2020) found that BL enhanced the knowledge of public health students in Korea, attributing this to easier material access and the ability to review difficult content outside of class time. Shimizu & Kang (2025) also noted that BL directly influenced learning satisfaction for these students. Furthermore, Roos & Bagger (2024) confirmed that knowledge impacts learning satisfaction in nursing students. Murillo-Zamorano & Montanero (2018) reinforced this by finding that knowledge significantly affected student learning satisfaction in flipped classrooms. Critically, Sojayapan & Khlaisang (2020) specifically highlighted that flipped classrooms could influence student learning satisfaction mediated by knowledge. Synthesising these findings, it is hypothesised that:

H6: Blended Learning Affects Student Mathematics Learning Satisfaction in Indonesia, Mediated by Knowledge.

Blended Learning and Skill and Learning Satisfaction

Developing expertise and technological skills is often promoted through blended learning (BL (Zagouras et al., 2022). By utilising BL, students are trained to manage assignment deadlines independently, thereby improving essential self-management skills, which are particularly crucial in mathematics learning due to its often higher level of complexity. Studies have shown a positive impact of BL on skills (Chaeruman et al., 2020). Moradimokhles & Hwang (2022) found that BL influenced students' English language skills in clinical supervisor training attributing its effectiveness to higher efficiency.

Additionally, Fisher et al., (2021) demonstrated that BL positively influences student learning satisfaction in Australian universities. This is often because the blended methods allow students to access materials at any time, facilitating an adjustment of the learning process to their individual needs. Crucially, skill plays a vital role in supporting learning satisfaction. Murillo-Zamorano & Montanero (2018) explained that students' expertise in flipped classrooms can significantly influence their learning satisfaction, as skilled students are better prepared to utilise this learning model effectively. Maarif et al. (2022) also showed that skills lead to higher learning satisfaction in the flipped classroom system. Integrating these insights, it is hypothesised that:

H7: Blended Learning (BL) affects students' Mathematics Learning Satisfaction in Indonesia, mediated by skill.

Blended Learning and Knowledge and Skills

By combining face-to-face instruction with online learning elements, **BL** offers inherent flexibility that enhances student knowledge and facilitates learner interaction (Tubagus et al., 2020). In mathematics, **BL** enables students to learn fundamental concepts independently through digital resources while utilising face-to-face sessions to deepen their understanding of more complex topics (Mullen et al., 2023). The knowledge acquired through such independent learning not only aids students in grasping theoretical concepts but also cultivates vital analytical and problem-solving skills essential for mathematics learning. Empirical evidence

supports this link: Wawro & Serbin (2025) showed that **BL** effectively improved nursing students' knowledge. Alonso et al. (2025) also highlighted that **BL** provided easier access to materials, enabling students to repeatedly review difficult sections outside of class to deepen their understanding.

Furthermore, research indicates a direct link between **BL** and skills and knowledge. Roos & Bagger (2024) stated that **BL** influenced students' skills in nursing education, attributing this to the flexibility that allows self-paced learning combined with direct lecturer supervision for practical skill perfection. More specifically, Altas & Mede (2021) found that knowledge significantly influenced students' skills in using flipped classrooms. Hankeln & Prediger (2025) also clarified that knowledge impacts students' listening and reading skills. Given these sequential relationships, it is hypothesised that:

H8: Blended Learning affects students' mathematics learning skills in Indonesia through the mediation of knowledge.

Knowledge, Skill and Learning Satisfaction

Knowledge is the cornerstone of the learning process, particularly in complex disciplines such as mathematics (Gildore et al., 2025). It enables students to comprehend theory and effectively utilise their skills in solving more challenging mathematical problems (Manson & Ayres, 2021). Strong knowledge is, therefore, expected to enhance students' skills, which, in turn, will significantly contribute to their learning satisfaction. Students with robust knowledge tend to develop more effective skills, which directly enhance their process (Strohmaier et al., 2020). Consequently, the synergistic presence of knowledge and skills is anticipated to facilitate a more meaningful mathematics learning experience, leading to higher levels of student satisfaction (Gurmu et al., 2024).

Various studies support this mediated relationship. Pongsakdi et al. (2020) demonstrated a significant influence of knowledge on students' listening and reading comprehension skills. Geiger et al. (2023) similarly showed that students' knowledge capacity positively affected their oral presentation skills, as good knowledge often correlates with increased confidence in conveying information and structuring ideas.

Furthermore, Zhang et al. (2021) found that knowledge influenced learning satisfaction in nursing students, emphasising its critical role in creating an optimal mathematics learning experience for academic achievement. On the other hand, Murillo-Zamorano & Montanero (2018) the study explained that students' expertise in the flipped classroom significantly influenced their learning satisfaction, as skilled students are better prepared for face-to-face sessions due to their foundational independent learning. Shlomo & Rosenberg-Kima (2024) also reinforced that skills lead to higher learning satisfaction in the flipped classroom system. Based on these cumulative findings, it is hypothesised that:

H9: Knowledge influences the Learning Satisfaction of mathematics students in Indonesia through Skill mediation.

Research Methodology

This study employed a quantitative survey methodology to collect data. The survey was conducted online to gather information from university students across Indonesia who had prior experience with blended learning (BL) in mathematics. A **snowball sampling** method was utilised to recruit participants. This approach involved initially recruiting respondents through social networks, who then referred to other relevant individuals from their contacts. This technique was chosen due to its practicality in accessing specialised and geographically dispersed populations of students engaged in blended mathematics learning. However, it is crucial to acknowledge that the effectiveness and efficiency of snowball sampling are largely contingent on the personal and professional networks of the researcher (Iska et al., 2023). Furthermore, the reliance on self-referral in snowball sampling reduces the sample's representativeness of the findings to the broader student population in Indonesia. This lack of control over the sampling process means the sample may exhibit a degree of homogeneity, potentially overlooking diverse perspectives outside the initially engaged networks (Siri et al., 2020).

The questionnaire was structured into several distinct sections. It began with demographic inquiries, such as age, gender, and education level, and subsequently posed questions about respondents' experience with the BL method for mathematics. The online format of the survey ensured broad reach and convenient access for participants. A total of 304 students' responses were collected and deemed eligible for analysis, encompassing diverse demographics regarding gender, education level, and gadget usage across various islands in Indonesia (See Table 1 for detailed sample characteristics).

Table 1. Demographic Respondents

Variable	Demographic	Total	Percentage
Gender	Male	142	46,71
	Female	162	53,29
Island	Sumatera	45	14,80
	Java	142	46,71
	Kalimantan	76	25,00
	Sulawesi	41	13,49
Level of education	Undergraduate Degree	221	72,70
	Postgraduate Degree	52	17,11
	Doctoral Degree	31	10,20
Gadgets most often used for studying	Smartphone	129	42,43
	Tablet	21	6,91
	Computer	33	10,86
	Laptop	121	39,80

The core variables measured in this study included Blended Learning (BL), Knowledge (KN), Skill (SK), and Learning Satisfaction (LS). Each variable was assessed using a **5-point Likert scale**, ranging from 1 ('strongly disagree') to 5 ('strongly agree'), to gauge respondents' perceptions across the various dimensions investigated. This 5-point scale was specifically chosen for its widespread use and familiarity in educational research, which enhances

comparability, its balanced structure provides sufficient nuance without overwhelming respondents (Riyadh et al., 2019). While acknowledging the ordinal nature of Likert scale data, it is a common practice in PLS-SEM to treat such data as suitable for path analysis, given its non-parametric algorithm and robustness (Hair et al., 2023). A detailed description of each variable and its measurement is provided below :

- **Blended Learning (BL):** This construct measures the perceived effectiveness of BL in the educational context, encompassing aspects such as time flexibility, ease of material access, and the seamless integration of online and face-to-face learning components. The measurement items for BL were adapted from established instruments by Birbal et al., (2018) and Yehia et al. (2022).
- **Knowledge (KN):** This variable assessed students' depth of understanding regarding mathematical concepts delivered through BL. The questions aimed to evaluate conceptual clarity, comprehension of presented material, and the ability to apply theoretical knowledge effectively. KN measurement items were adapted from previous studies, notably (Murillo-Zamorano & Montanero, 2018).
- **Skill (SK):** This construct focuses on students' proficiency in solving mathematical problems and their adeptness in utilising the tools and resources available on the BL platform. Relevant items included analytical skills, problem-solving capabilities, and applying acquired knowledge in practical situations. Murillo-Zamorano & Montanero (2018) adapted SK measurement items from prior research.
- **Learning Satisfaction (LS):** This variable measures a student's overall satisfaction with their learning experience. It specifically included items evaluating satisfaction with the BL methodology, the teaching efficacy of lecturers, and the perceived growth in their knowledge and skills. The LS measurement items were adapted from previous studies by Huang, (2021) and Sun et al. (2008).

Data analysis was performed using the **Structural Equation Model - Partial Least Squares (SEM-PLS) method**. This approach was chosen for its suitability in handling complex research models with multiple independent, mediating, and dependent variables, its strong emphasis on predictive power by maximising variance explained in endogenous constructs, and its fewer assumptions regarding data distribution, which is beneficial for data collected via Likert scales (Hair et al., 2023; Henseler et al., 2016). The analysis proceeded in two principal stages, adhering to the recommendations put forth by Hair et al., (2023); Henseler et al., (2016), and Rigdon et al. (2017).

The initial stage involved the **Evaluation of the Measurement Model**, which was crucial for establishing the reliability and construct validity of research variables: Blended Learning, Knowledge, Skill, and Learning Satisfaction. This phase ensured that each construct was consistently and accurately measured. Specifically, **reliability** was assessed through internal consistency using **Cronbach's Alpha (α)** and **Composite Reliability (CR)**. **Validity** was established by examining **convergent validity** (using Average Variance Extracted [AVE] values and indicator outer loadings) and **discriminant validity** (using the Heterotrait-Monotrait Ratio [HTMT] criterion). Additionally, **content validity** was ensured through expert

review of the questionnaire items to confirm their relevance and comprehensiveness (as noted in the instrument description).

Following the successful validation of the measurement model, the subsequent stage involved evaluating **the Structural Model**. This phase focused on testing the hypothesised relationships between the identified latent variables. Path analysis examined both direct and indirect effects among these variables. To robustly assess the significance of these direct and indirect paths, a bootstrap resampling technique with 5,000 samples was employed. This approach yields a more robust estimation of standard errors, thereby providing a more precise determination of the statistical significance of the effects observed between variables.

Results and discussions

Evaluation Measurement Model

Before proceeding with hypothesis testing, a rigorous evaluation of the measurement model was conducted to establish the reliability and validity of all constructs. This critical step encompassed assessments of indicator reliability, internal consistency reliability, convergent validity, and discriminant validity, adhering to the established guidelines outlined by (Hair et al., 2023).

Indicator Reliability

Indicator reliability was initially assessed by examining the outer loading (OL) values. These values quantify the extent to which the variance of each indicator is explained by its underlying construct, thereby reflecting the reliability of the indicator. The widely accepted recommendation for outer loading values is greater than 0.70. As presented in Table 2, all outer loading values in this study surpassed this threshold, confirming that the indicator reliability for all constructs has been robustly met.

Internal Consistency Reliability

Cronbach's Alpha (α) and Composite Reliability (CR) were evaluated to ascertain the internal consistency reliability. These metrics are crucial for determining the degree to which indicators designed to measure the same latent construct are intercorrelated and consistent. As shown in Table 2, both the Cronbach's Alpha and Composite Reliability values for all constructs exceeded 0.70. This outcome indicates that the indicators employed in this study are internally consistent and can, therefore, be considered as reliable, fully aligning with the recommendations provided by Hair et al. (2023).

Convergent Validity

Convergent validity was assessed through the Average Variance Extracted (AVE). The AVE value indicates the variance a construct explains in its indicators relative to the amount of variance due to measurement error. A high AVE value signifies that all items within a construct converge well, collectively explaining a substantial portion of their shared variance. Manley et al., (2021) recommend an AVE value of 0.50 or higher. As evidenced in Table 2, all AVE

values in this study were greater than 0.50, thus confirming the convergent validity of all constructs.

Discriminant Validity

Discriminant Validity was examined to ensure that each construct is empirically distinct and sufficiently differentiated from other constructs within the structural model. Henseler et al., (2015) recommend utilizing the Heterotrait-Monotrait (HTMT) for a more robust discriminant validity assessment, with a recommended threshold value below 0.90. Based on the results presented in Table 3, all HTMT values were below 0.90. This outcome unequivocally indicates that discriminant validity has been established for all constructs, rendering them suitable for subsequent analysis within the structural model.

Table 2: Outer Loading and Convergent Validity

Variable	Item	OL	α	CR	AVE
Knowledge	KNO 1	0,924	0,795	0,907	0,829
	KNO 2	0,897			
Blended Learning	Online Learning	0,789	0,834	0,877	0,508
	Learning Flexibility	0,903			
	LF 1	0,740			
	LF 2	0,853			
	LF 3	0,827			
Online Learning	OL 1	0,735	0,938	0,951	0,766
	OL 2	0,872			
	OL 3	0,888			
	OL 4	0,888			
Learning Satisfaction	LS 1	0,821			
	LS 2	0,839			
	LS 3	0,906			
	LS 4	0,924			
	LS 5	0,889			
	LS 6	0,867			
Skill	SKI 1	0,856	0,916	0,935	0,706
	SKI 2	0,867			
	SKI 3	0,736			
	SKI 4	0,833			
	SKI 5	0,880			
	SKI 6	0,860			

Notes: OL= Outer Loading, CR = Composite Reliability, AVE= Average Variance Extracted

Table 3:

	Blended Learning	Knowledge	Learning Satisfaction	Skill
Blended Learning				
Knowledge	0,400			
Learning Satisfaction	0,477	0,785		
Skill	0,526	0,827	0,705	

Evaluation of the Structural Model

Hypothesis testing was conducted by analysing the path coefficients and their statistical significance. This was achieved through a robust bootstrapping procedure involving 5000 resamples with a 95% bootstrap confidence level, as Henseler et al. (2016) recommended. The results for each hypothesised path are presented in detail below and are summarised comprehensively in Table 4.

H1: Blended Learning (->) knowledge ($\beta= 0.329$, T-stat 5.529, $p<0.001$). The direct effect of **Blended Learning (BL)** on **Knowledge (KN)** is **positive and significant**, thus providing strong support for **H1**. This finding robustly indicates that the strategic implementation of BL notably enhances students' knowledge acquisition. This result is consistent with the extant literature, particularly Al-Mekhlafi et al., (2025), which posits that BL facilitates easier access for students to revisit challenging material, thereby deepening their comprehension of complex mathematical concepts. The inherent flexibility of BL, which allows students to learn at their own pace, is profoundly important in mathematics. This subject often demands extensive time and repeated exposure to grasp abstract concepts.

Furthermore, the expensive access to diverse digital resources, such as interactive modules and video tutorials, empowers students to explore various cognitive pathways to internalise complex mathematical ideas. Liebendörfer et al., (2023) underscored that the BL methodology can significantly augment student engagement and motivation, particularly for demanding subjects like mathematics, owing to its adaptable learning styles. This finding aligns with research indicating that knowledge acquired through BL transcends mere theoretical understanding, encompassing the ability to apply concepts in broader contexts.

H2: Blended Learning (->) skill ($\beta=0.252$, T-stat=6.032, $p<0.001$). The direct effect of **Blended Learning (BL)** on **Skill (SK)** is also **positive and significant**, confirming the acceptance of **H2**. This underscores that BL effectively contributes to the development of students' mathematical skills. Sukkamart et al., (2025) emphasise the critical role of skills in technology-enhanced learning environments, where BL uniquely enables students to hone the technical and analytical proficiencies indispensable for solving complex mathematical problems. The strategic integration of technology within the learning process, including online discussion forums and computer-based practice exercises, provides invaluable opportunities for students to practice and apply their mathematical knowledge in practical situations actively. This finding resonates strongly with Dwi Lestari & Riatus, (2024), who demonstrated that BL substantially increases students' skills by fostering independent learning and the flexible application of relevant abilities across diverse scenarios. In mathematics, BL is instrumental in helping students practice problem-solving as frequently as needed to solidify their understanding.

H3: Knowledge (->) Skill ($\beta=0.625$, T-stat= 14.792, $p<0.001$) The path from **Knowledge (KN)** to **Skill (SK)** exhibits a powerful positive and significant, profoundly indicating that higher levels of knowledge lead to significant improvements in with the pedagogical principle that a solid and deep knowledge base forms the essential foundation for cultivating higher-order skills, particularly in complex subjects such as mathematics. In mathematics education,

an in-depth understanding of theoretical concepts provides students with a robust framework to apply their comprehension in practical contexts, including rigorous problem-solving and comprehensive analysis. According to Sanusi (2022), the knowledge acquired through blended learning, it empowers students to enhance their problem-solving capabilities by providing access to diverse digital resources that facilitate a deeper conceptual understanding. With a firm theoretical grasp, students are better prepared to apply their knowledge in real-world scenarios, which, in turn, sharpens their critical and analytical thinking skills. Moreover, Xu et al., (2023) highlighted that declarative knowledge (factual and conceptual understanding) frequently serves as the indispensable precursor for the development of procedural skills (the “how-to” aspect of problem-solving), both of which are paramount in mathematics learning. Students with strong declarative knowledge are better equipped to develop procedural skills, such as solving complex equations or intricate problems, which facilitates the emergence of more sophisticated skills, including critical thinking and advanced problem-solving abilities. Within the BL context, students can strategically utilise various online materials to reinforce their foundational knowledge, subsequently applying that knowledge in practice questions or collaborative disciplines that demand high-level problem-solving skills.

H4: Knowledge (->) Learning Satisfaction ($\beta=0.442$, $T\text{-stat}=7.186$, $p<0.001$) The relationship between **Knowledge (KN)** and **Learning Satisfaction (LS)** demonstrates strong **positive and significant effect**, suggesting that students who possess greater knowledge exhibit higher satisfaction with their learning experience. This supports **H4**. The acquisition of knowledge during the learning process has a significant and direct impact on learning satisfaction. This suggests that **students with sufficient knowledge are generally more satisfied** with their learning experience. This finding is entirely consistent with research Alrajhi (2024), which indicates that increased knowledge during the learning process contributes to elevated learning satisfaction, particularly when students feel empowered to apply their acquired knowledge in a practical context. In mathematics education, learning satisfaction is frequently correlated with how thoroughly students grasp the concepts taught and their demonstrable ability to solve related problems. When students perceive that they gain a deep understanding of mathematical topics through BL, their satisfaction with the learning process markedly increases as they feel more prepared and confident in navigating academic challenges.

H5: Skill (->) Learning Satisfaction ($\beta=0.342$, $T\text{-stat}=4.985$, $p<0.001$) The effect of **Skill (SK)** on **Learning Satisfaction (LS)** is also **significant and positive**, implying that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, **H5 is supported**. This study found that the skills students acquired during their learning journey significantly contributed to their overall learning satisfaction. Brandsæter & Berge, (2025) articulated that students with superior skills in utilising learning technology typically report higher satisfaction with their learning process, primarily because they feel more capable of solving problems and effectively managing their independent learning. In the domain of mathematics education, skills cultivated through BL, such as analytical thinking and problem-solving capabilities, instil greater self-confidence in students, which ultimately translates into increased satisfaction. Students who perceive they have developed competencies relevant to

1 mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied
2 because they can discern the practical applications of their newly acquired knowledge. This
3 finding is further reinforced by Fan et al., (2022), which states that skills developed through
4 technology-based learning substantially increase student satisfaction, as these skills better
5 equip them to confront challenges in the real-world challenges.

6 Indirect Effects (Mediation Analysis)

7 The study also thoroughly investigated the **indirect effects** to ascertain the crucial mediating
8 roles of **Knowledge** and **Skill** within the hypothesised relationships.

9 **H6: Blended Learning (->) Knowledge (->) Learning Satisfaction ($\beta=0.145$, T-stat=4.272,**
10 **$p<0.001$)** The indirect effects of BL on Learning Satisfaction **through Knowledge** are
11 **significant**, providing clear support for **H6**. This mediation effect profoundly highlights the
12 **important role of knowledge acquisition** in bridging the relationship between BL and
13 students' learning satisfaction, especially in the context of mathematics. BL, with its integrated
14 approach that combines online and face-to-face instruction, provides students with enhanced
15 overall learning satisfaction.

16 **H7: Blended Learning (->) Skill (->) Learning Satisfaction ($\beta=0.086$, T-stat=3.669,**
17 **$p<0.001$)**. The indirect effects of BL on Learning Satisfaction **through Skill** are also
18 **significant**, although with a comparatively smaller effect size. This finding supports **H7**. This
19 suggests that BL indirectly contributes to learning satisfaction by fostering the development of
20 essential skills. As observed in this study, the acquisition of enhanced skills confers higher self-
21 confidence on students, which, in turn, significantly enhances their satisfaction with the
22 learning experience. Cevikbas & Kaiser (2023) demonstrated that students who feel proficient
23 in utilising learning technology and are adept at applying mathematical concepts tend to be
24 more satisfied with their learning process. In mathematics education, skills cultivated through
25 BL, such as the ability to solve complex problems or fully utilise mathematical technology
26 (e.g., graphing calculators, modelling software), play a pivotal role in increasing students' self-
27 confidence. The more skilled students become in leveraging these tools, the more satisfied they
28 are with their learning outcomes (Engelbrecht & Borba, 2024). This indirect effect illustrates
29 that BL not only confers direct benefits in skill enhancement but also contributes to increased
30 student learning satisfaction through the holistic development of these crucial skills.

31 **H8: Blended Learning (->) Knowledge (->) Skill ($\beta=0.206$, T-stat= 5.290, $p<0.001$)** The
32 indirect effects of BL Sill **through Knowledge** are **significant**, profoundly indicating that
33 **knowledge** acts as a crucial mediator between BL experiences and subsequent skill
34 development. This provides robust support for **H8**. Knowledge indeed serves as a potent
35 mediator in the relationship between BL and skills. As highlighted in the seminal study by
36 Sukkamart et al., (2025), a robust theoretical knowledge base often forms an indispensable
37 foundation for the development of practical skills. In the context of mathematical education,
38 students who possess a deep and nuanced understanding of mathematical theories are
39 inherently better at applying this intricate knowledge in solving real-world problems, which
40 demonstrably improves their skills. BL uniquely provides students with the opportunity to learn
41 mathematics in diverse formats (such as comprehensive texts, engaging videos, and interactive

exercises), allowing them to learn in a manner that optimally suits their learning styles. The profound knowledge gained through this dynamic method then empowers students to develop superior skills in solving mathematical problems, both within the structured confines of the classroom and in broader, real-life contexts. Tran & O'Connor (2024) found that knowledge acquired through online learning contributed significantly to the development of practical skills in domains requiring deep conceptual understanding, including mathematics.

H9: Knowledge (->) Skill (->) Learning Satisfaction ($\beta=0.214$, T-stat=4.777, $p<0.001$) The final mediation effect of knowledge on learning Satisfaction **through Skill is significant**, unequivocally indicating that **skills** act as a critical mediator between knowledge acquisition and learning satisfaction. This leads to the acceptance of **H9**. Students who cultivate a deep understanding of mathematical concepts are considerably more likely to effectively apply their knowledge in practical situations, which directly fosters superior skill development. Demir et al. (2022) found that declarative knowledge (theoretical understanding) frequently functions as an important foundation for the development of procedural skills (practical application). In mathematics education, strong theories of knowledge empower students to develop more sophisticated analytical and problem-solving skills, ultimately leading to increased learning satisfaction. Within the BL environment, the profound knowledge gained through various online resources enables students to actively practice and strengthen their skills in solving mathematical problems. These enhanced skills contribute to achieving better academic results and significantly increase students' satisfaction with the learning process, as they feel more prepared and competent to overcome academic challenges effectively.

Table 4: Path Coefficients, Effect Size, and Collinearity Test

	β	T-stats	P-Values	VIF	f2
BL -> KNO	0,329	5,529	0,000	1,000	0,122
BL -> SKI	0,252	6,032	0,000	1,122	0,128
KNO -> LS	0,442	7,186	0,000	2,003	0,206
KNO -> SKI	0,625	14,792	0,000	1,122	0,786
SKI -> LS	0,342	4,985	0,000	2,003	0,123
BL -> KNO -> LS	0,145	4,272	0,000	-	-
BL -> KNO -> SKI	0,206	5,290	0,000	-	-
BL -> SKI -> LS	0,086	3,669	0,000	-	-
KNO -> SKI -> LS	0,214	4,777	0,000	-	-

Coefficients of Determination (R2)

The coefficients of determination (R2) quantify the proportion of variance in the endogenous construct that the exogenous construct within the research model can explain. Hair et al. (2022) provide general guidelines, suggesting that R2 values of 0.25, 0.50, and 0.75 typically indicate weak, moderate, and strong levels of explanatory power, respectively. As presented in Table 5, the Adjusted R2 values for this study demonstrate that the model effectively explains 52.3% of the variation in Learning Satisfaction and 55.4% of the variation in Skill. This suggests that the construct of BL, Knowledge, and Skill, as conceptualised in this model, collectively exhibit

a moderate to strong explanatory power over student learning satisfaction and skill development in mathematics.

Table 5: Coefficient of Determination

	R-square	Adjusted R-square
Knowledge	0,108	0,106
Learning Satisfaction	0,526	0,523
Skill	0,557	0,554

Effect Size (f^2)

Effect Size (f^2) is a crucial metric employed in SEM analysis to measure the substantive impact of an exogenous construct on an endogenous construct. This is achieved by calculating the R^2 value after systematically removing one exogenous construct at a time (Hair et al., 2023). Y. Li (2022) established widely accepted benchmarks, categorising f^2 values of 0.02 as a small effect, 0.15 as a moderate effect, and 0.35 as a significant effect. For example, as detailed in **Table 4**, the effect of Knowledge on Skill ($f^2 = 0.786$) is substantial, unequivocally indicating a significant and profound contribution of knowledge to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also demonstrate moderate effects, further underscoring the critical importance of knowledge acquisition in shaping positive learning outcomes within an educational context.

Potential Causes for Variations from Related Studies

While the findings of this study broadly resonate with the growing body of literature on the benefits of BL, academic rigour demands an acknowledgement that research outcomes can exhibit variations across different studies. Such discrepancies are not uncommon and often stem from a confluence of interconnected factors. One primary contributor to these variations is BL's specific modality and implementation. The precise balance between online and face-to-face components, the specific digital tools and platforms employed, and the underlying pedagogical approaches adopted can differ significantly between studies (Alonso et al., 2025; Engelbrecht & Borba, 2024; Tubagus et al., 2020). For instance, a BL model that is heavily reliant on synchronous online discussions might yield different results than one that emphasises asynchronous interactive modules, leading to distinct impacts on student engagement and learning outcomes.

Furthermore, contextual factors play a profound role in shaping research findings. The cultural and educational landscape in which a study is conducted, including the specific characteristics of the Indonesian higher education system, unique student demographics, pre-existing levels of technological exposure, and the prevailing digital infrastructure, can all profoundly influence how students perceive, adapt to, and ultimately benefit from BL. These localised variables can create subtle yet significant differences in learning experiences compared to studies conducted in, for example, Western educational settings with different pedagogical traditions or access to technology, highlighting the importance of situated learning perspectives (Kyei-Akuoko et al., 2025). Similarly, discipline-specific nuances are also critical. While this study focused on mathematics, the effectiveness of BL and the precise mediating roles of knowledge and skill may vary across diverse academic disciplines, owing to inherent differences in subject matter

complexity, district learning objectives, and the unique cognitive skills required for mastery in each field (Liebendörfer et al., 2023).

Finally, variations can also arise from methodological differences, including the operationalisation and measurement of constructs such as “Knowledge,” “Skill,” and “Learning Satisfaction.” Different measurement instruments or scales can capture distinct facets of these constructs, influencing the observed relationship (Engelbrecht & Borba, 2024). Additionally, the characteristics of the student samples, such as their academic background, intrinsic motivation levels, or prior digital literacy, while the sampling methodologies employed the use of non-probability sampling, which, as a limitation of this study, can impact generalizability, can lead to notable differences in findings when comparing across studies (Meikleham & Hugo, 2020). Acknowledging these potential sources of variation is fundamental for a nuanced interpretation of research findings and for advancing a more sophisticated understanding of BL’s complex effectiveness across diverse educational landscapes.

Implications for Higher Education

The robust findings from this study offer a profound understanding and carry significant, actionable implications for educational institutions, particularly within the dynamic landscape of mathematics teaching in Indonesian higher education. Since BL has been demonstrably proven effective in significantly improving key student learning outcomes, specifically fostering deeper Knowledge acquisition and enhancing essential skills development (as evidenced by the current study’s findings, consistent with broader trends noted by Abuhassna et al., (2020) — its strategic application and broader integration within higher education curricula should be a paramount priority for institutions.

Higher education institutions should consider several key focus areas to optimise the utilisation of these valuable research results. Firstly, there is a compelling need to prioritise and invest in developing highly interactive and contextually relevant digital content. This includes designing and providing a rich array of engaging online learning materials, such as sophisticated simulations, adaptive interactive exercises, and meticulously produced high-quality video tutorials, all meticulously tailored to address the unique complexities of mathematical concepts (Strohmaier et al., 2020). Such a proactive approach will support diverse learning styles and empower students to achieve self-paced mastery, a critical component of deep learning in mathematics. Secondly, institutions must continue to strengthen and enhance their online learning platforms. This entails investing in robust, intuitively designed, and user-friendly digital environments that actively support rich interaction, foster collaborative activities, and facilitate effective and timely feedback mechanisms (Shi et al., 2023). These platforms are supplementary tools and the central infrastructure through which BL can deliver flexible access and promote the deep, engaged learning essential for mathematical proficiency.

Furthermore, providing comprehensive technological support necessitates ensuring a seamless and supportive learning experience. This means providing readily available and expert technical assistance to students and lecturers, designed to address technological challenges promptly. By proactively mitigating potential technical frustrations, institutions can ensure that

all users can optimally leverage the BL methodology without hindrance. Crucially, a pivotal implication lies in investing in targeted professional development for lecturers. This requires dedicated, ongoing training programs that focus on practical pedagogical approaches for seamlessly integrating the BL strategy (Dwi Lestari & Riatun, 2024). Such training should cover best practices for combining face-to-face and online components, fostering vibrant online discussions, designing authentic assessments within blended learning environments, and utilising innovative digital tools to enhance mathematical understanding and application (Cai et al., 2020; Källberg & Roos, 2025). Such comprehensive training is not just about adopting technology; it is about cultivating a more dynamic, relevant and responsive learning environment that genuinely meets the evolving needs of students and comprehensively promotes their holistic intellectual and practical development. By strategically implementing these multifaceted recommendations, higher education institutions in Indonesia can effectively harness the full transformative potential of BL, thereby significantly improving mathematical literacy, fostering crucial skills, and ultimately elevating overall student learning satisfaction.

Conclusion

This study set out to analyse the impact of Blended Learning (BL) on students' Learning Satisfaction (LS) in mathematics, specifically examining the mediating roles of Knowledge (KN) and Skill (SK). Our findings reveal that BL has a significant influence on students' knowledge and Skills. Specifically, BL enables students to access learning materials more flexibly and engage with them more deeply, which demonstrably contributes to an enhanced understanding of mathematical concepts. This improved knowledge then directly impacts students' Skills in solving mathematical problems. Furthermore, the enhanced Skill acquired by students directly increases their Learning Satisfaction, as students feel more confident and capable when confronting academic challenges. These results underscore a robust chain effect: BL positively fosters Knowledge, which enhances Skill, ultimately leading to greater Learning Satisfaction.

These findings carry important implications for educational institutions, particularly within the context of mathematics teaching in Indonesian higher education. Since BL has proven effective in improving student learning outcomes, its application should be expanded and further integrated into higher education curricula. For effective policymaking, institutions should prioritise providing more interactive digital content, robust online learning platforms, and comprehensive technological support to ensure students can optimally leverage the BL method. Furthermore, investing in targeted training for lecturers to integrate BL more effectively is crucial. This will help cultivate a more dynamic and relevant learning environment that meets student needs and promotes holistic development.

Despite these significant contributions, this study is subject to several limitations that warrant consideration for future research. First, the reliance on snowball sampling may have limited the generalizability of our findings, as the resulting sample may not be fully representative of the diverse student population across Indonesia. Second, adopting a cross-sectional design restricts our ability to capture dynamic changes in student behaviour or identify the long-term effects of BL on learning satisfaction over time.

For future research endeavours, we recommend employing a longitudinal design to better track changes in student attitudes and behaviours within a BL context, as well as using extended representative sampling techniques to enhance the generalizability of findings. Further avenues for exploration could include investigating other influential variables, such as self-regulation, technology acceptance, or learning engagement, as potential factors that contribute to the success of BL in fostering student learning satisfaction.

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Please accept my sincere apologies for the delay in submitting this review. I took the time to carefully and thoroughly evaluate the revised manuscript entitled "The Impact of Blended Learning on Knowledge, Skills, and Satisfaction in Mathematics: A Study in Indonesian Universities." The delay was due to my commitment to ensuring a meticulous review of the revisions made by the authors.

Having examined the manuscript in detail, I can confirm that the authors have addressed all of my previous concerns in a satisfactory manner. The revisions have substantially improved the quality of the paper. The structure is now clearer, the methodology more robust, and the discussion more insightful and well-grounded in relevant literature. The study's contribution to the field of mathematics education, particularly within the Indonesian higher education context, is now articulated more convincingly.

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The impact of blended learning on knowledge, skills and satisfaction in mathematics: a study in Indonesian universities AQ1

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Abstract

AQ2 Blended learning, a method that combines face-to-face and online instruction, has had a significant impact on higher education due to the rapid advancement of information and communication technology. This study analysed the effect of blended learning on students' knowledge, skills and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial

Least Squares (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study offers valuable insights for optimising curriculum design in higher education to enhance the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

KEYWORDS

Blended learning; knowledge; Skill; learning satisfaction; higher education mathematics education; Structural equation model

SUBJECTS

Social Sciences; Education; Higher Education; Study of Higher Education; Teaching & Learning

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Introduction

The rapid evolution of information and communication technology (ICT) has profoundly reshaped operational paradigms across various institutions, with higher education undergoing a significant transformation (Abdi et al., [2025](#)). Global data indicate a widespread adoption of technology, impacting multiple sectors, including education (Tamphu et al., [2024](#)). This pervasive integration facilitates a learning ecosystem that transcends traditional boundaries of time and location. In higher education, technology has become integral to the learning process, empowering students to access course materials and engage in discussions with both instructors and peers online, thereby diminishing their reliance on the physical classroom as the sole learning environment (Alshurideh et al., [2023](#)). This paradigm shift underscores technology's pivotal role in fostering a more dynamic and adaptive learning culture.

The surge in online learning was notably accelerated by the COVID-19 pandemic, which

necessitated the closure of educational institutions worldwide and the abrupt shift to remote instruction (Gal & Geiger, 2022; Metaferia et al., 2023). While the pandemic subsided in 2021, enabling the resumption of face-to-face learning, including in Indonesia (Park et al., 2023), the integration of online learning systems within universities has persisted. Students often prefer online learning due to its perceived time-saving benefits and enhanced personal focus (Dolenc & Brumen, 2024). This enduring preference has fostered a new educational culture in Indonesia, characterised by a combination of face-to-face and online learning, commonly known as blended learning (BL) (Dwi Lestari & Riatun, 2024; Hill & Smith, 2023).

BL, a hybrid system that integrates face-to-face and online or distance learning, offers flexibility that aligns with student needs, enabling more effective time management and a more conducive study environment (Al-Mekhlafi et al., 2025). In Indonesia, several universities have significantly adopted BL environments, with some reaching up to 80% implementation (Prahmana et al., 2021). However, a recognised challenge within BL, particularly in mathematics instruction, lies in the subject's inherent 'higher level of complexity' (Alonso et al., 2025). Students frequently encounter difficulties comprehending digitally delivered mathematics content (Cho & Kim, 2020). The successful implementation of BL hinges on universities' ability to integrate it with their academic policies seamlessly (Buhl-Wiggers et al., 2023). When universities meticulously design curricula to integrate mathematics learning within a blended framework, it can significantly enhance student learning satisfaction and foster the development of both academic and non-academic skills.

Conversely, Hill and Smith (2023) emphasised that the success of a BL system is contingent upon the students' foundational knowledge. Students' ability to effectively integrate the mathematics learning system with BL methods within their academic environment is directly related to their existing knowledge (Awajan et al., 2024). This encompasses their technological proficiency, as students lacking adequate digital skills may face barriers in accessing materials, which can diminish their overall satisfaction with the mathematics learning process (Mullen et al., 2025).

Prior research has investigated the impact of BL on student satisfaction across diverse geographical contexts, including Australia with McCarthy et al. (2025), China with Wu (2024) and Ghana with Bervell and Umar (2020). These studies consistently reported a significant positive influence of BL

on student learning satisfaction in these regions. Studies on BL in mathematics have shown that it can improve mathematical thinking skills, foster positive perceptions, enhance learning outcomes and increase self-regulation and problem-solving abilities (Ali, [2024](#); Awajan et al., [2024](#); Hill & Smith, [2023](#); Kyei-Akuoko et al., [2025](#); Mullen et al., [2025](#); Sanusi, [2022](#)).

Specifically, within the Indonesian context, research about BL has predominantly focused on factors such as character, attitude, environment, social factors and usage intentions (Dwi Lestari & Riatun, [2024](#); Prahmana et al., [2021](#)). Furthermore, as noted by Mullen et al. ([2025](#)), the efficacy of BL in mathematics instruction remains a subject of considerable debate. Therefore, a significant research gap exists regarding the specific impact of BL on student satisfaction in mathematics learning within Indonesia, particularly concerning the mediating roles of knowledge and skills. This study aims to address a critical gap by exploring factors that influence student satisfaction in the mathematics learning system in Indonesia, particularly given the limited research on these specific factors in recent years. The Indonesian context is particularly pertinent due to its vast and diverse higher education landscape, ongoing digital transformation initiatives and unique cultural approaches to education, which may influence the dynamics of BL adoption and its outcomes. Indonesia's commitment to improving its PISA scores in mathematics, which have historically been low (Gildore et al., [2025](#)). Makes understanding practical pedagogical approaches, such as BL, particularly crucial in this context.

Building upon the assertions of Prifti ([2022](#)) and Al-Mekhlafi et al. ([2025](#)), which highlight the dependence of BL success on students' knowledge and expertise, this research posits knowledge and skills as mediating factors. The study aims to investigate whether robust knowledge and relevant skills influence Indonesian students' satisfaction with mathematics learning when adopting the BL method. This research is anticipated to serve as a vital reference for educational institutions, enabling them to comprehend the factors influencing student satisfaction in blended mathematics learning. Such insights will facilitate the adjustment of learning methods to better align with student needs and foster a more active academic environment that embraces technology in teaching and learning, especially in mathematics.

Theoretical framework

Blended learning

According to Alonso et al. (2025), BL is an educational system that effectively combines structured face-to-face instruction with flexible, independent online learning, leveraging digital technology. This system offers significant convenience in terms of time, place and learning methods, allowing students to access materials more flexibly (Uz & Uzun, 2018). The flexibility is particularly beneficial for university students, who often manage demanding schedules that encompass both academic and extracurricular commitments. Buhl-Wiggers et al. (2023) noted that BL empowers students with direct instruction from lecturers in class and access to rich digital resources such as videos, interactive modules and online discussion forums, which are highly valuable even in mathematics learning. Students who are comfortable with technology and adept at independent learning tend to report higher satisfaction due to their ability to control their independent learning trend to report higher satisfaction due to their ability to control their learning pace (Tubagus et al., 2020). However, this system also inherently demands a higher level of students' discipline and responsibility (Xu et al., 2023). When coupled with adequate institutional support and a well-designed curriculum, implementing BL can significantly enhance the quality of the learning experience and foster greater student satisfaction (Sukkamart et al., 2025; Višňovská & Cortina, 2025).

The impact of BL on student learning satisfaction has been consistently noted. As mentioned, students' comfort with technology and capacity for independent learning often correlate with increased satisfaction, given their enhanced control over their learning rhythm (Rasheed et al., 2020). Furthermore, students' foundational knowledge of basic concepts critically influences the effectiveness of their engagement with BL (Li et al., 2022). Lazarevic and Bentz (2021) highlight that students with strong knowledge of the subject matter are better equipped to access, comprehend and apply information presented online and face-to-face. This foundational knowledge also encompasses students' expertise in leveraging technology to ensure success within the BL environment (Rasheed et al., 2020). Essential skills such as digital literacy, managing technological devices and effective communication are crucial. Students proficient in technological skills exhibit greater adaptability to the BL system, overcoming potential challenges and significantly enhancing

their overall learning satisfaction (Engelbrecht & Borba, 2024).

Blended learning and knowledge

Knowledge, as defined by Gayed (2025), is the accumulation of information, facts, skills and understanding acquired through individual experience and education. Broadly, knowledge can be categorised into declarative knowledge (of facts and concepts) and procedural knowledge (of how to perform tasks) (Barbieri & Booth, 2020). Knowledge forms the primary foundation for effective learning in education, especially in mathematics. By integrating face-to-face and online methods, BL can influence and enrich students' mathematical knowledge (Liebendörfer et al., 2023). This model provides wider access to diverse digital information sources, including learning videos and discussion forums, thereby supporting the enrichment of students' declarative knowledge (Mullen et al., 2025). Moreover, the inherent flexibility of BL empowers students to manage their study time and location according to their individual needs, fostering independent exploration of the material (Kyei-Akuoko et al., 2025). Through online accessible learning, students engage with core mathematical concepts and participate in practical applications that reinforce their holistic understanding.

Several prior studies corroborate the positive effect of BL on knowledge acquisition. For instance, Liebendörfer et al. (2023) demonstrated that BL effectively improved nursing students' knowledge, facilitating better knowledge acquisition and task completion. Similarly, Al-Mekhlafi et al. (2025) found that BL enhanced the public health knowledge of students in Korea, attributing this to easier access to materials and the ability to review challenging sections outside of class time. Kyei-Akuoko et al. (2025) further supported this, suggesting that BL can increase student knowledge by minimising fatigue and enhancing focus. Based on these consistent findings, it is hypothesised that:

H1:

Blended Learning (BL) positively affects student knowledge in mathematics learning in Indonesia.

Blended learning and skill

As defined by Sukkamart et al. (2025), it refers to an individual's ability to perform specific tasks or jobs proficiently and efficiently. Skills can encompass cognitive, technical, social or managerial

competencies developed through continuous learning and experience (Liu & Yushchik, 2024). Within the educational context, student skills pertinent to BL in mathematics include critical thinking, problem-solving, communication and technical proficiency (Al-Mekhlafi et al., 2025). BL uniquely offers students opportunities to apply their mathematical knowledge through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Kyei-Akuoko et al., 2025). Engelbrecht and Borba (2024). Furthermore, it is highlighted that integrating technology in learning facilitates cross-geographic collaboration via online platforms, fostering the development of broader communication and teamwork skills. Thus, beyond offering flexibility, BL cultivates a rich environment for developing essential mathematical skills in students.

Empirical evidence supports the positive impact of BL on skill development. Moradimokhles and Hwang (2022) found that BL significantly improved students' English language skills. Li et al. (2019) [Li et al (2022)] similarly reported that BL substantially enhanced the skills of nursing students, attributing this to the flexibility it provides for students to access materials at their own pace and according to their learning style. Chaeruman et al. (2020) also confirmed that BL significantly influenced skills in clinical supervisor training, noting its higher efficiency. Based on these findings, it is hypothesised that:

H2:

Blended Learning (BL) positively affects student skills in learning mathematics in Indonesia.

Knowledge and skill

Knowledge is fundamental to students' mathematics learning process, forming the bedrock for developing more complex skills (Espinoza-Vásquez et al., 2025). In an academic setting, knowledge directly influences how students approach problem-solving, make informed decisions and cultivate professional-level skills (Yang et al., 2022). The critical importance of knowledge lies in its transformative ability to shape skills. A solid knowledge base empowers students to grasp mathematical concepts in depth and effectively apply that understanding to practical situations (Quintos et al., 2025). Furthermore, contemporary education emphasises skills beyond mere cognitive knowledge, expecting students to possess strong problem-solving, critical thinking and

adaptive skills to navigate the dynamic changes in mathematics learning (Aoki et al., 2025).

Additionally, robust knowledge enables students to access diverse perspectives, enriching their critical and innovative thinking skills. Thus, knowledge is not merely a passive repository but an active resource that drives innovative skills and effective problem-solving (Franco & DeLuca, 2019)

[delete.]. Research consistently demonstrates this relationship. Murillo-Zamorano and Montanero (2018) found that knowledge significantly influences students' skills in using flipped classrooms.

Alfian et al. (2024) [delete reference] further substantiated this, reporting a significant impact of knowledge on students' listening and reading comprehension skills. (Murillo-Zamorano & Montanero, 2018) also reinforced this by showing that students' knowledge capacity positively affects their oral presentation skills. Given these established links, it is hypothesised that:

H3:

Blended Learning (BL) positively affects students' knowledge in mathematics learning in Indonesia.

Knowledge and learning satisfaction

Knowledge is the primary foundation that influences how students comprehend mathematical material and apply it in various contexts (Ibrahim & Alhosani, 2020). In mathematics, this knowledge extends beyond mere facts and theories to encompass the critical analysis abilities needed to interpret information (Barbieri & Booth, 2020). The deeper and more critical a student understands a concept, the greater their satisfaction in studying mathematics (Krawitz et al., 2025). In this context, student learning satisfaction refers to the level of pleasure and contentment students derive from their mathematics learning experience (Wong & Chapman, 2023). This satisfaction is intrinsically linked to how the knowledge acquired impacts their learning journey (Akbar et al., 2025). Students with profound mathematical knowledge are better equipped to assimilate new material, leading to higher satisfaction. Conversely, a lack of knowledge can lead to confusion, frustration and decreased motivation, ultimately reducing their satisfaction with mathematics learning (Haghighat et al., 2023). Therefore, knowledge is crucial in fostering a positive mathematics learning experience and promoting optimal academic achievement for students.

Prior studies consistently affirm that knowledge influences satisfaction. Haghighat et al. (2023) found that knowledge has a positive impact on learning satisfaction among nursing students. Murillo-Zamorano and Montanero (2018) similarly observe that knowledge significantly influenced students' learning satisfaction in the flipped classroom, mainly because students were required to engage with the material before face-to-face sessions, forming a foundational understanding for discussions. Abuhassna et al. (2020) also emphasised that the quality of knowledge directly affects learning satisfaction in both undergraduate and postgraduate students, enabling them to achieve their academic goals more effectively. Based on these findings, it is hypothesised that:

H4:

Knowledge positively affects the mathematics learning satisfaction of students in Indonesia.

Skill and learning satisfaction

Skills represent an individual's learned and experienced abilities, enabling them to perform specific tasks effectively (Smith, 2022). In higher education mathematics, students' foundational skills are crucial to their ability to absorb and apply material effectively in practical situations (Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022). Students who perceive themselves as possessing adequate skills tend to exhibit greater confidence, which enhances their ability to understand mathematical material deeply and fosters a sense of self-satisfaction (Alonso et al., 2025). For example, Murillo-Zamorano and Montanero (2018) reported that students' expertise in utilising flipped classrooms significantly affected their learning satisfaction. This is because students proficient in independent learning and time management skills are better equipped to effectively leverage the flipped classroom model. Yoo and Cho (2020) further demonstrated that skills can lead to higher learning satisfaction within the flipped classroom system, given its perceived efficiency in terms of time and place, allowing students to tailor their learning style. Based on these preceding findings, it is hypothesised that:

H5:

Skill positively affects the mathematics learning of students in Indonesia.

Blended learning, knowledge and learning satisfaction

BL, as an instructional method that integrates face-to-face and online components, offers a flexible approach that accommodates diverse student learning styles and fosters deeper knowledge acquisition (Yehia et al., 2022). In supporting mathematics learning, the blended approach enables students to access information independently and flexibly, thereby profoundly increasing their in-depth knowledge. The broader access to materials afforded by BL also facilitates their mathematical exploration of subjects of interest (Okai-Ugbaje et al., 2020). Enhanced knowledge, in turn, strengthens conceptual understanding in applying BL methods and boosts students' confidence in mastering mathematical knowledge due to BL. It is expected to increase their overall learning satisfaction and encourage continuous engagement (Al-Mekhlafi et al., 2025).

Previous research provides empirical support for this mediated relationship. Adi and Fathoni (2020) demonstrated that BL effectively improved nursing students' knowledge. Similarly, Julia et al. (2020) found that BL enhanced the knowledge of public health students in Korea, attributing this to easier material access and the ability to review difficult content outside of class time. Shimizu and Kang (2025) also noted that BL directly influenced learning satisfaction for these students. Furthermore, Roos and Bagger (2024) confirmed that knowledge impacts learning satisfaction in nursing students. Murillo-Zamorano and Montanero (2018) reinforced this by finding that knowledge significantly affected student learning satisfaction in flipped classrooms. Critically, Sojayapan and Khlaisang (2018) specifically highlighted that flipped classrooms could influence student learning satisfaction mediated by knowledge. Synthesising these findings, it is hypothesised that:

H6:

Blended learning affects student mathematics learning satisfaction in Indonesia, Mediated by Knowledge.

Blended learning and skill and learning satisfaction

Developing expertise and technological skills is often promoted through blended learning (BL) (Zagouras et al., 2022). By utilising BL, students are trained to manage assignment deadlines independently, thereby improving essential self-management skills, which are particularly crucial in mathematics learning due to its often higher level of complexity. Studies have shown a positive

impact of BL on skills (Chaeruman et al., 2020). Moradimokhles and Hwang (2022) found that BL influenced students' English language skills in clinical supervisor training attributing its effectiveness to higher efficiency.

Additionally, Fisher et al. (2021) demonstrated that BL positively influences student learning satisfaction in Australian universities. This is often because the blended methods allow students to access materials at any time, facilitating an adjustment of the learning process to their individual needs. Crucially, skill plays a vital role in supporting learning satisfaction. Murillo-Zamorano and Montanero (2018) explained that students' expertise in flipped classrooms can significantly influence their learning satisfaction, as skilled students are better prepared to utilise this learning model effectively. Maarif et al. (2022) also showed that skills lead to higher learning satisfaction in the flipped classroom system. Integrating these insights, it is hypothesised that:

H7:

Blended Learning (BL) affects students' mathematics learning satisfaction in Indonesia, mediated by skill.

Blended learning and knowledge and skills

By combining face-to-face instruction with online learning elements, **BL** offers inherent flexibility that enhances student knowledge and facilitates learner interaction (Tubagus et al., 2020). In mathematics, **BL** enables students to learn fundamental concepts independently through digital resources while utilising face-to-face sessions to deepen their understanding of more complex topics (Mullen et al., 2025). The knowledge acquired through such independent learning not only aids students in grasping theoretical concepts but also cultivates vital analytical and problem-solving skills essential for mathematics learning. Empirical evidence supports this link: Wawro and Serbin (2025) showed that **BL** effectively improved nursing students' knowledge. Alonso et al. (2025) also highlighted that **BL** provided easier access to materials, enabling students to repeatedly review difficult sections outside of class to deepen their understanding.

Furthermore, research indicates a direct link between **BL** and skills and knowledge. Roos and Bagger (2024) stated that **BL** influenced students' skills in nursing education, attributing this to the

flexibility that allows self-paced learning combined with direct lecturer supervision for practical skill perfection. More specifically, Altas and Mede (2020) found that knowledge significantly influenced students' skills in using flipped classrooms. Hankeln and Prediger (2025) also clarified that knowledge impacts students' listening and reading skills. Given these sequential relationships, it is hypothesised that:

H8:

Blended Learning affects students' mathematics learning skills in Indonesia through the mediation of knowledge.

Knowledge, skill and learning satisfaction

Knowledge is the cornerstone of the learning process, particularly in complex disciplines such as mathematics (Gildore et al., 2025). It enables students to comprehend theory and effectively utilise their skills in solving more challenging mathematical problems (Manson & Ayres, 2021). Strong knowledge is, therefore, expected to enhance students' skills, which, in turn, will significantly contribute to their learning satisfaction. Students with robust knowledge tend to develop more effective skills, which directly enhance their process (Strohmaier et al., 2020). Consequently, the synergistic presence of knowledge and skills is anticipated to facilitate a more meaningful mathematics learning experience, leading to higher levels of student satisfaction (Gurmu et al., 2024).

Various studies support this mediated relationship. Pongsakdi et al. (2020) demonstrated a significant influence of knowledge on students' listening and reading comprehension skills. Geiger et al. (2023) similarly showed that students' knowledge capacity positively affected their oral presentation skills, as good knowledge often correlates with increased confidence in conveying information and structuring ideas.

Furthermore, Zhang et al. (2021) found that knowledge influenced learning satisfaction in nursing students, emphasising its critical role in creating an optimal mathematics learning experience for academic achievement. On the other hand, Murillo-Zamorano and Montanero (2018) the study explained that students' expertise in the flipped classroom significantly influenced their learning

satisfaction, as skilled students are better prepared for face-to-face sessions due to their foundational independent learning. Shlomo and Rosenberg-Kima (2025) also reinforced that skills lead to higher learning satisfaction in the flipped classroom system. Based on these cumulative findings, it is hypothesised that:

H9:

Knowledge influences the learning satisfaction of mathematics students in Indonesia through Skill mediation.

Research methodology

This study employed a quantitative survey methodology to collect data. The survey was conducted online to gather information from university students across Indonesia who had prior experience with blended learning (BL) in mathematics. A *snowball sampling* method was utilised to recruit participants. This approach involved initially recruiting respondents through social networks, who then referred to other relevant individuals from their contacts. This technique was chosen due to its practicality in accessing specialised and geographically dispersed populations of students engaged in blended mathematics learning. However, it is crucial to acknowledge that the effectiveness and efficiency of snowball sampling are largely contingent on the personal and professional networks of the researcher (Iska et al., 2023). Furthermore, the reliance on self-referral in snowball sampling reduces the sample's representativeness of the findings to the broader student population in Indonesia. This lack of control over the sampling process means the sample may exhibit a degree of homogeneity, potentially overlooking diverse perspectives outside the initially engaged networks (Siri et al., 2020).

The questionnaire was structured into several distinct sections. It began with demographic inquiries, such as age, gender and education level, and subsequently posed questions about respondents' experience with the BL method for mathematics. The online format of the survey ensured broad reach and convenient access for participants. A total of 304 students' responses were collected and deemed eligible for analysis, encompassing diverse demographics regarding gender, education level and gadget usage across various islands in Indonesia (See Table 1 for detailed sample

characteristics).

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Table 1. Demographic respondents.

Variable	Demographic	Total	Percentage
Gender	Male	142	46.71
	Female	162	53.29
Island	Sumatera	45	14.80
	Java	142	46.71
	Kalimantan	76	25.00
	Sulawesi	41	13.49
Level of education	Undergraduate Degree	221	72.70
	Postgraduate Degree	52	17.11
	Doctoral Degree	31	10.20
Gadgets most often used for studying	Smartphone	129	42.43
	Tablet	21	6.91
	Computer	33	10.86
	Laptop	121	39.80

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The core variables measured in this study included Blended Learning (BL), Knowledge (KN), Skill (SK) and Learning Satisfaction (LS). Each variable was assessed using a 5-point Likert scale, ranging from 1 ('strongly disagree') to 5 ('strongly agree'), to gauge respondents' perceptions across the various dimensions investigated. This 5-point scale was specifically chosen for its widespread use and familiarity in educational research, which enhances comparability. Its balanced structure provides sufficient nuance without overwhelming respondents (Riyadh et al., 2019). While acknowledging the ordinal nature of Likert scale data, it is a common practice in PLS-SEM to treat

such data as suitable for path analysis, given its non-parametric algorithm and robustness (Hair et al., 2023). A detailed description of each variable and its measurement is provided below:

- **Blended Learning (BL):** This construct measures the perceived effectiveness of BL in the educational context, encompassing aspects such as time flexibility, ease of material access and the seamless integration of online and face-to-face learning components. The measurement items for BL were adapted from established instruments by Birbal et al. (2018) and Yehia et al. (2022).
- **Knowledge (KN):** This variable assessed students' depth of understanding regarding mathematical concepts delivered through BL. The questions aimed to evaluate conceptual clarity, comprehension of presented material and the ability to apply theoretical knowledge effectively. KN measurement items were adapted from previous studies, notably (Murillo-Zamorano & Montanero, 2018).
- **Skill (SK):** This construct focuses on students' proficiency in solving mathematical problems and their adeptness in utilising the tools and resources available on the BL platform. Relevant items included analytical skills, problem-solving capabilities and applying acquired knowledge in practical situations. Murillo-Zamorano and Montanero (2018) adapted SK measurement items from prior research.
- **Learning Satisfaction (LS):** This variable measures a student's overall satisfaction with their learning experience. It specifically included items evaluating satisfaction with the BL methodology, the teaching efficacy of lecturers and the perceived growth in their knowledge and skills. The LS measurement items were adapted from previous studies by Huang (2021) and Sun et al. (2008).

Data analysis was performed using the Structural Equation Model - Partial Least Squares (SEM-PLS) method. This approach was chosen for its suitability in handling complex research models with multiple independent, mediating and dependent variables, its strong emphasis on predictive power by maximising variance explained in endogenous constructs, and its fewer assumptions regarding data distribution, which is beneficial for data collected via Likert scales (Hair et al., 2023; Henseler et al., 2016). The analysis proceeded in two principal stages, adhering to the recommendations put

forth by Hair et al. (2023), Henseler et al. (2016) and Rigdon et al. (2017).

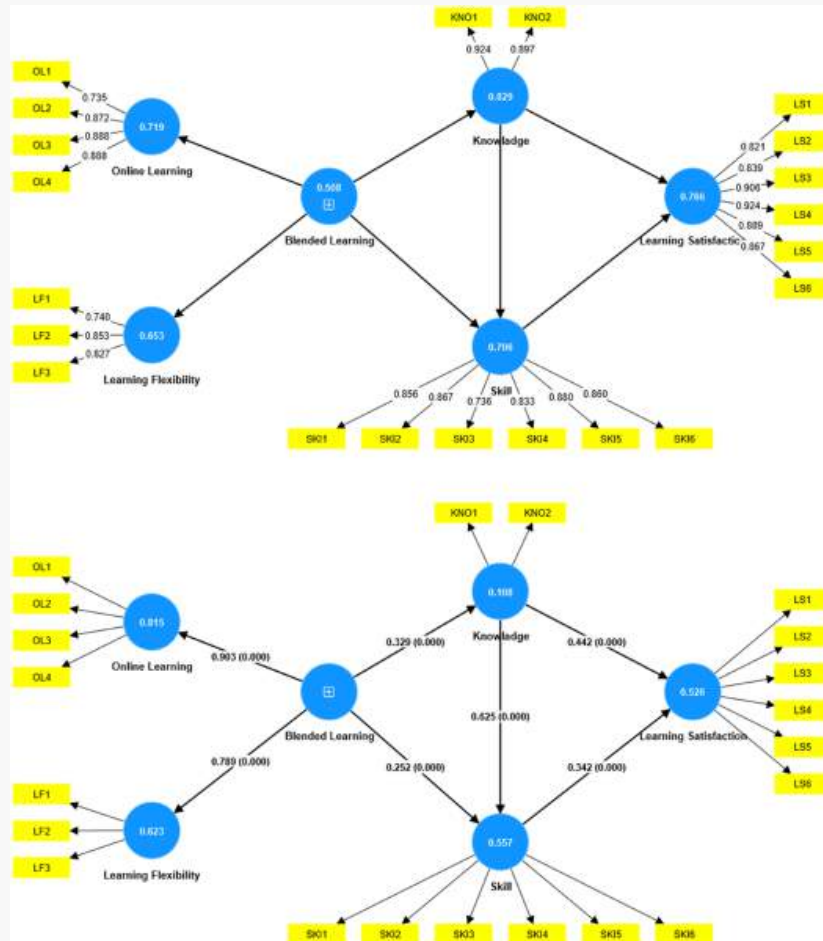
The initial stage involved the Evaluation of the Measurement Model, which was crucial for establishing the reliability and construct validity of research variables: Blended Learning, Knowledge, Skill and Learning Satisfaction. This phase ensured that each construct was consistently and accurately measured. Specifically, reliability was assessed through internal consistency using Cronbach's Alpha (α) and Composite Reliability (CR). Validity was established by examining convergent validity (using Average Variance Extracted [AVE] values and indicator outer loadings) and discriminant validity (using the Heterotrait-Monotrait Ratio [HTMT] criterion). Additionally, content validity was ensured through expert review of the questionnaire items to confirm their relevance and comprehensiveness (as noted in the instrument description).

Following the successful validation of the measurement model, the subsequent stage involved evaluating the Structural Model. This phase focused on testing the hypothesised relationships between the identified latent variables. Path analysis examined both direct and indirect effects among these variables. To robustly assess the significance of these direct and indirect paths, a bootstrap resampling technique with 5,000 samples was employed. This approach yields a more robust estimation of standard errors, thereby providing a more precise determination of the statistical significance of the effects observed between variables.

Results and discussions

This section presents the findings derived from the statistical analysis, specifically focusing on the evaluation of the measurement model and the structural model. We detail the outcomes of our investigation into the hypothesized relationships between the identified latent variables, followed by a comprehensive discussion that interprets these results in the context of existing literature and their implication for mathematics education (Figure 1).

Figure 1. Outer and inner model.



Evaluation measurement model

Before proceeding with hypothesis testing, a rigorous evaluation of the measurement model was conducted to establish the reliability and validity of all constructs. This critical step encompassed assessments of indicator reliability, internal consistency reliability, convergent validity and discriminant validity, adhering to the established guidelines outlined by Hair et al. (2023).

Indicator reliability

Indicator reliability was initially assessed by examining the outer loading (OL) values. These values

quantify the extent to which the variance of each indicator is explained by its underlying construct, thereby reflecting the reliability of the indicator. The widely accepted recommendation for outer loading values is greater than 0.70. As presented in [Table 2](#), all outer loading values in this study surpassed this threshold, confirming that the indicator reliability for all constructs has been robustly met.

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Table 2. Outer loading and convergent validity.

Variable	Item	OL	α	CR	AVE
Knowledge	KNO 1	0.924	0.795	0.907	0.829
	KNO 2	0.897			
Blended learning	Online learning	0.789	0.834	0.877	0.508
	Learning flexibility	0.903			
Learning flexibility	LF 1	0.740			
	LF 2	0.853			
	LF 3	0.827			
Online learning	OL 1	0.735			
	OL 2	0.872			
	OL 3	0.888			
	OL 4	0.888			
Learning satisfaction	LS 1	0.821	0.938	0.951	0.766
	LS 2	0.839			
	LS 3	0.906			
	LS 4	0.924			
	LS 5	0.889			
	LS 6	0.867			
Skill	SKI 1	0.856	0.916	0.935	0.706
	SKI 2	0.867			
	SKI 3	0.736			
	SKI 4	0.833			
	SKI 5	0.880			
	SKI 6	0.860			

Notes: OL = Outer Loading, CR = Composite Reliability, AVE = Average Variance Extracted.

Internal consistency reliability

Cronbach's Alpha (α) and Composite Reliability (CR) were evaluated to ascertain the internal consistency reliability. These metrics are crucial for determining the degree to which indicators designed to measure the same latent construct are intercorrelated and consistent. As shown in [Table 2](#), both the Cronbach's Alpha and Composite Reliability values for all constructs exceeded 0.70. This outcome indicates that the indicators employed in this study are internally consistent and can, therefore, be considered as reliable, fully aligning with the recommendations provided by Hair et al. (2023).

Convergent validity

Convergent validity was assessed through the Average Variance Extracted (AVE). The AVE value indicates the variance a construct explains in its indicators relative to the amount of variance due to measurement error. A high AVE value signifies that all items within a construct converge well, collectively explaining a substantial portion of their shared variance. Manley et al. (2021) recommend an AVE value of 0.50 or higher. As evidenced in [Table 2](#), all AVE values in this study were greater than 0.50, thus confirming the convergent validity of all constructs.

Discriminant validity

Discriminant Validity was examined to ensure that each construct is empirically distinct and sufficiently differentiated from other constructs within the structural model. Henseler et al. (2015) recommend utilizing the Heterotrait-Monotrait (HTMT) for a more robust discriminant validity assessment, with a recommended threshold value below 0.90. Based on the results presented in [Table 3](#), all HTMT values were below 0.90. This outcome unequivocally indicates that discriminant validity has been established for all constructs, rendering them suitable for subsequent analysis within the structural model.

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Table 3. Discriminant validity

	Blended learning	Knowledge	Learning satisfaction	Skill
Blended learning				
Knowledge	0.400			
Learning satisfaction	0.477	0.785		
Skill	0.526	0.827	0.705	

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Evaluation of the structural model

Hypothesis testing was conducted by analysing the path coefficients and their statistical significance. This was achieved through a robust bootstrapping procedure involving 5000 resamples with a 95% bootstrap confidence level, as Henseler et al. (2016) recommended. The results for each hypothesised path are presented in detail below and are summarised comprehensively in Table 4.

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Table 4. Path coefficients, effect size and collinearity test.

	β	T-stats	P-values	VIF	f ²
BL -> KNO	0.329	5.529	0.000	1.000	0.122
BL -> SKI	0.252	6.032	0.000	1.122	0.128
KNO -> LS	0.442	7.186	0.000	2.003	0.206
KNO -> SKI	0.625	14.792	0.000	1.122	0.786
SKI -> LS	0.342	4.985	0.000	2.003	0.123
BL -> KNO -> LS	0.145	4.272	0.000	—	—

BL -> KNO -> SKI	0.206	5.290	0.000	–	–
BL -> SKI -> LS	0.086	3.669	0.000	–	–
KNO -> SKI -> LS	0.214	4.777	0.000	–	–

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H1: Blended Learning (->) knowledge ($\beta = 0.329$, T-stat 5.529, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Knowledge (KN)** is **positive and significant**, thus providing strong support for **H1**. This finding robustly indicates that the strategic implementation of BL notably enhances students' knowledge acquisition. This result is consistent with the extant literature, particularly Al-Mekhlafi et al. (2025), which posits that BL facilitates easier access for students to revisit challenging material, thereby deepening their comprehension of complex mathematical concepts. The inherent flexibility of BL, which allows students to learn at their own pace, is profoundly important in mathematics. This subject often demands extensive time and repeated exposure to grasp abstract concepts.

Furthermore, the expensive access to diverse digital resources, such as interactive modules and video tutorials, empowers students to explore various cognitive pathways to internalise complex mathematical ideas. Liebendörfer et al. (2023) underscored that the BL methodology can significantly augment student engagement and motivation, particularly for demanding subjects like mathematics, owing to its adaptable learning styles. This finding aligns with research indicating that knowledge acquired through BL transcends mere theoretical understanding, encompassing the ability to apply concepts in broader contexts.

H2: Blended Learning (->) skill ($\beta = 0.252$, T-stat = 6.032, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Skill (SK)** is also **positive and significant**, confirming the acceptance of **H2**. This underscores that BL effectively contributes to the development of students' mathematical skills. Sukkamart et al. (2025) emphasise the critical role of skills in technology-enhanced learning environments, where BL uniquely enables students to hone the technical and analytical proficiencies

indispensable for solving complex mathematical problems. The strategic integration of technology within the learning process, including online discussion forums and computer-based practice exercises, provides invaluable opportunities for students to practice and apply their mathematical knowledge in practical situations actively. This finding resonates strongly with Dwi Lestari and Riatun (2024), who demonstrated that BL substantially increases students' skills by fostering independent learning and the flexible application of relevant abilities across diverse scenarios. In mathematics, BL is instrumental in helping students practice problem-solving as frequently as needed to solidify their understanding.

H3: Knowledge (->) Skill ($\beta = 0.625$, T-stat= 14.792, $p < 0.001$) The path from **Knowledge (KN)** to **Skill (SK)** exhibits a powerful positive and significant, profoundly indicating that higher levels of knowledge lead to significant improvements in with the pedagogical principle that a solid and deep knowledge base forms the essential foundation for cultivating higher-order skills, particularly in complex subjects such as mathematics. In mathematics education, an in-depth understanding of theoretical concepts provides students with a robust framework to apply their comprehension in practical contexts, including rigorous problem-solving and comprehensive analysis. According to Sanusi (2022), the knowledge acquired through blended learning, it empowers students to enhance their problem-solving capabilities by providing access to diverse digital resources that facilitate a deeper conceptual understanding. With a firm theoretical grasp, students are better prepared to apply their knowledge in real-world scenarios, which, in turn, sharpens their critical and analytical thinking skills. Moreover, Xu et al. (2023) highlighted that declarative knowledge (factual and conceptual understanding) frequently serves as the indispensable precursor for the development of procedural skills (the 'how-to' aspect of problem-solving), both of which are paramount in mathematics learning. Students with strong declarative knowledge are better equipped to develop procedural skills, such as solving complex equations or intricate problems, which facilitates the emergence of more sophisticated skills, including critical thinking and advanced problem-solving abilities. Within the BL context, students can strategically utilise various online materials to reinforce their foundational knowledge, subsequently applying that knowledge in practice questions or collaborative disciplines that demand high-level problem-solving skills.

H4: Knowledge (->) Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186, $p < 0.001$) The relationship between **Knowledge (KN)** and **Learning Satisfaction (LS)** demonstrates strong **positive and significant effect**, suggesting that students who possess greater knowledge exhibit higher satisfaction with their learning experience. This supports **H4**. The acquisition of knowledge during the learning process has a significant and direct impact on learning satisfaction. This suggests that *students with sufficient knowledge are generally more satisfied* with their learning experience. This finding is entirely consistent with research Alrajhi (2024), which indicates that increased knowledge during the learning process contributes to elevated learning satisfaction, particularly when students feel empowered to apply their acquired knowledge in a practical context. In mathematics education, learning satisfaction is frequently correlated with how thoroughly students grasp the concepts taught and their demonstrable ability to solve related problems. When students perceive that they gain a deep understanding of mathematical topics through BL, their satisfaction with the learning process markedly increases as they feel more prepared and confident in navigating academic challenges.

H5: Skill (->) Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985, $p < 0.001$). The effect of **Skill (SK)** on **Learning Satisfaction (LS)** is also **significant and positive**, implying that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, **H5 is supported**. This study found that the skills students acquired during their learning journey significantly contributed to their overall learning satisfaction. Brandsæter and Berge (2025) articulated that students with superior skills in utilising learning technology typically report higher satisfaction with their learning process, primarily because they feel more capable of solving problems and effectively managing their independent learning. In the domain of mathematics education, skills cultivated through BL, such as analytical thinking and problem-solving capabilities, instil greater self-confidence in students, which ultimately translates into increased satisfaction. Students who perceive they have developed competencies relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they can discern the practical applications of their newly acquired knowledge. This finding is further reinforced by Fan et al. (2022), which states that skills developed through technology-based learning substantially increase student satisfaction, as these skills better equip them to confront challenges in real-world challenges.

Indirect effects (mediation analysis)

The study also thoroughly investigated the *indirect effects* to ascertain the crucial mediating roles of *Knowledge* and *Skill* within the hypothesised relationships.

H6: Blended Learning (->) Knowledge (->) Learning Satisfaction ($\beta = 0.145$, T-stat = 4.272, $p < 0.001$) The indirect effects of BL on Learning Satisfaction **through Knowledge** are **significant**, providing clear support for **H6**. This mediation effect profoundly highlights the *important role of knowledge acquisition* in bridging the relationship between BL and students' learning satisfaction, especially in the context of mathematics. BL, with its integrated approach that combines online and face-to-face instruction, provides students with enhanced overall learning satisfaction.

H7: Blended Learning (->) Skill (->) Learning Satisfaction ($\beta = 0.086$, T-stat = 3.669, $p < 0.001$). The indirect effects of BL on Learning Satisfaction **through Skill** are also **significant**, although with a comparatively smaller effect size. This finding supports **H7**. This suggests that BL indirectly contributes to learning satisfaction by fostering the development of essential skills. As observed in this study, the acquisition of enhanced skills confers higher self-confidence on students, which, in turn, significantly enhances their satisfaction with the learning experience. Cevikbas and Kaiser (2023) demonstrated that students who feel proficient in utilising learning technology and are adept at applying mathematical concepts tend to be more satisfied with their learning process. In mathematics education, skills cultivated through BL, such as the ability to solve complex problems or fully utilise mathematical technology (e.g. graphing calculators, modelling software), play a pivotal role in increasing students' self-confidence. The more skilled students become in leveraging these tools, the more satisfied they are with their learning outcomes (Engelbrecht & Borba, 2024). This indirect effect illustrates that BL not only confers direct benefits in skill enhancement but also contributes to increased student learning satisfaction through the holistic development of these crucial skills.

H8: Blended Learning (->) Knowledge (->) Skill ($\beta = 0.206$, T-stat= 5.290, $p < 0.001$) The indirect effects of BL Sill **through Knowledge** are **significant**, profoundly indicating that **knowledge** acts as a crucial mediator between BL experiences and subsequent skill development.

This provides robust support for **H8**. Knowledge indeed serves as a potent mediator in the relationship between BL and skills. As highlighted in the seminal study by Sukkamart et al. (2025), a robust theoretical knowledge base often forms an indispensable foundation for the development of practical skills. In the context of mathematical education, students who possess a deep and nuanced understanding of mathematical theories are inherently better at applying this intricate knowledge in solving real-world problems, which demonstrably improves their skills. BL uniquely provides students with the opportunity to learn mathematics in diverse formats (such as comprehensive texts, engaging videos and interactive exercises), allowing them to learn in a manner that optimally suits their learning styles. The profound knowledge gained through this dynamic method then empowers students to develop superior skills in solving mathematical problems, both within the structured confines of the classroom and in broader, real-life contexts. Tran and O'Connor (2024) found that knowledge acquired through online learning contributed significantly to the development of practical skills in domains requiring deep conceptual understanding, including mathematics.

H9: Knowledge (->) Skill (->) Learning Satisfaction ($\beta = 0.214$, T-stat = 4.777, $p < 0.001$) The final mediation effect of knowledge on learning Satisfaction **through Skill** is **significant**, unequivocally indicating that **skills** act as a critical mediator between knowledge acquisition and learning satisfaction. This leads to the acceptance of **H9**. Students who cultivate a deep understanding of mathematical concepts are considerably more likely to effectively apply their knowledge in practical situations, which directly fosters superior skill development. Demir et al. (2022) found that declarative knowledge (theoretical understanding) frequently functions as an important foundation for the development of procedural skills (practical application). In mathematics education, strong theories of knowledge empower students to develop more sophisticated analytical and problem-solving skills, ultimately leading to increased learning satisfaction. Within the BL environment, the profound knowledge gained through various online resources enables students to actively practice and strengthen their skills in solving mathematical problems. These enhanced skills contribute to achieving better academic results and significantly increase students' satisfaction with the learning process, as they feel more prepared and competent to overcome academic challenges effectively.

Coefficients of determination (R2)

The coefficients of determination (R2) quantify the proportion of variance in the endogenous construct that the exogenous construct within the research model can explain. Hair et al. (2023) provide general guidelines, suggesting that R2 values of 0.25, 0.50 and 0.75 typically indicate weak, moderate and strong levels of explanatory power, respectively. As presented in Table 5, the Adjusted R2 values for this study demonstrate that the model effectively explains 52.3% of the variation in Learning Satisfaction and 55.4% of the variation in Skill. This suggests that the construct of BL, Knowledge and Skill, as conceptualised in this model, collectively exhibit a moderate to strong explanatory power over student learning satisfaction and skill development in mathematics.

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Table 5. Coefficient of determination.

	R-square	Adjusted R-square
Knowledge	0.108	0.106
Learning Satisfaction	0.526	0.523
Skill	0.557	0.554

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Effect size (f2)

Effect Size (f2) is a crucial metric employed in SEM analysis to measure the substantive impact of an exogenous construct on an endogenous construct. This is achieved by calculating the R2 value after systematically removing one exogenous construct at a time (Hair et al., 2023). Li et al. (2022) established widely accepted benchmarks, categorising f2 values of 0.02 as a small effect, 0.15 as a moderate effect, and 0.35 as a significant effect. For example, as detailed in Table 4, the effect of

Knowledge on Skill ($f^2 = 0.786$) is substantial, unequivocally indicating a significant and profound contribution of knowledge to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also demonstrate moderate effects, further underscoring the critical importance of knowledge acquisition in shaping positive learning outcomes within an educational context.

Potential causes for variations from related studies

While the findings of this study broadly resonate with the growing body of literature on the benefits of BL, academic rigour demands an acknowledgement that research outcomes can exhibit variations across different studies. Such discrepancies are not uncommon and often stem from a confluence of interconnected factors. One primary contributor to these variations is BL's specific modality and implementation. The precise balance between online and face-to-face components, the specific digital tools and platforms employed, and the underlying pedagogical approaches adopted can differ significantly between studies (Alonso et al., [2025](#); Engelbrecht & Borba, [2024](#); Tubagus et al., [2020](#)). For instance, a BL model that is heavily reliant on synchronous online discussions might yield different results than one that emphasises asynchronous interactive modules, leading to distinct impacts on student engagement and learning outcomes.

Furthermore, contextual factors play a profound role in shaping research findings. The cultural and educational landscape in which a study is conducted, including the specific characteristics of the Indonesian higher education system, unique student demographics, pre-existing levels of technological exposure and the prevailing digital infrastructure, can all profoundly influence how students perceive, adapt to and ultimately benefit from BL. These localised variables can create subtle yet significant differences in learning experiences compared to studies conducted in, for example, Western educational settings with different pedagogical traditions or access to technology, highlighting the importance of situated learning perspectives (Kyei-Akuoko et al., [2025](#)). Similarly, discipline-specific nuances are also critical. While this study focused on mathematics, the effectiveness of BL and the precise mediating roles of knowledge and skill may vary across diverse academic disciplines, owing to inherent differences in subject matter complexity, distinct learning objectives and the unique cognitive skills required for mastery in each field (Liebendörfer et al.,

2023).

Finally, variations can also arise from methodological differences, including the operationalisation and measurement of constructs such as ‘Knowledge’, ‘Skill’ and ‘Learning Satisfaction’. Different measurement instruments or scales can capture distinct facets of these constructs, influencing the observed relationship (Engelbrecht & Borba, 2024). Additionally, the characteristics of the student samples, such as their academic background, intrinsic motivation levels or prior digital literacy, while the sampling methodologies employed the use of non-probability sampling, which, as a limitation of this study, can impact generalizability, can lead to notable differences in findings when comparing across studies (Meikleham & Hugo, 2020). Acknowledging these potential sources of variation is fundamental for a nuanced interpretation of research findings and for advancing a more sophisticated understanding of BL’s complex effectiveness across diverse educational landscapes.

Implications for higher education

The robust findings from this study offer a profound understanding and carry significant, actionable implications for educational institutions, particularly within the dynamic landscape of mathematics teaching in Indonesian higher education. Since BL has been demonstrably proven effective in significantly improving key student learning outcomes, specifically fostering deeper Knowledge acquisition and enhancing essential skills development (as evidenced by the current study’s findings, consistent with broader trends noted by Abuhassna et al. (2020)—its strategic application and broader integration within higher education curricula should be a paramount priority for institutions.

Higher education institutions should consider several key focus areas to optimise the utilisation of these valuable research results. Firstly, there is a compelling need to prioritise and invest in developing highly interactive and contextually relevant digital content. This includes designing and providing a rich array of engaging online learning materials, such as sophisticated simulations, adaptive interactive exercises and meticulously produced high-quality video tutorials, all meticulously tailored to address the unique complexities of mathematical concepts (Strohmaier et al., 2020). Such a proactive approach will support diverse learning styles and empower students to achieve self-paced mastery, a critical component of deep learning in mathematics. Secondly, institutions must continue to strengthen and enhance their online learning platforms. This entails investing in robust,

intuitively designed and user-friendly digital environments that actively support rich interaction, foster collaborative activities and facilitate effective and timely feedback mechanisms (Shi et al., [2023](#)). These platforms are supplementary tools and the central infrastructure through which BL can deliver flexible access and promote the deep, engaged learning essential for mathematical proficiency.

Furthermore, providing comprehensive technological support necessitates ensuring a seamless and supportive learning experience. This means providing readily available and expert technical assistance to students and lecturers, designed to address technological challenges promptly. By proactively mitigating potential technical frustrations, institutions can ensure that all users can optimally leverage the BL methodology without hindrance. Crucially, a pivotal implication lies in investing in targeted professional development for lecturers. This requires dedicated, ongoing training programs that focus on practical pedagogical approaches for seamlessly integrating the BL strategy (Dwi Lestari & Riatun, [2024](#)). Such training should cover best practices for combining face-to-face and online components, fostering vibrant online discussions, designing authentic assessments within blended learning environments and utilising innovative digital tools to enhance mathematical understanding and application (Cai et al., [2020](#); Källberg & Roos, [2025](#)). Such comprehensive training is not just about adopting technology; it is about cultivating a more dynamic, relevant and responsive learning environment that genuinely meets the evolving needs of students and comprehensively promotes their holistic intellectual and practical development. By strategically implementing these multifaceted recommendations, higher education institutions in Indonesia can effectively harness the full transformative potential of BL, thereby significantly improving mathematical literacy, fostering crucial skills and ultimately elevating overall student learning satisfaction.

Conclusion

This study set out to analyse the impact of Blended Learning (BL) on students' Learning Satisfaction (LS) in mathematics, specifically examining the mediating roles of Knowledge (KN) and Skill (SK). Our findings reveal that BL has a significant influence on students' knowledge and Skills. Specifically, BL enables students to access learning materials more flexibly and engage with them

more deeply, which demonstrably contributes to an enhanced understanding of mathematical concepts. This improved knowledge then directly impacts students' Skills in solving mathematical problems. Furthermore, the enhanced Skill acquired by students directly increases their Learning Satisfaction, as students feel more confident and capable when confronting academic challenges. These results underscore a robust chain effect: BL positively fosters Knowledge, which enhances Skill, ultimately leading to greater Learning Satisfaction.

These findings carry important implications for educational institutions, particularly within the context of mathematics teaching in Indonesian higher education. Since BL has proven effective in improving student learning outcomes, its application should be expanded and further integrated into higher education curricula. For effective policymaking, institutions should prioritise providing more interactive digital content, robust online learning platforms and comprehensive technological support to ensure students can optimally leverage the BL method. Furthermore, investing in targeted training for lecturers to integrate BL more effectively is crucial. This will help cultivate a more dynamic and relevant learning environment that meets student needs and promotes holistic development.

Despite these significant contributions, this study is subject to several limitations that warrant consideration for future research. First, the reliance on snowball sampling may have limited the generalizability of our findings, as the resulting sample may not be fully representative of the diverse student population across Indonesia. Second, adopting a cross-sectional design restricts our ability to capture dynamic changes in student behaviour or identify the long-term effects of BL on learning satisfaction over time.

For future research endeavours, we recommend employing a longitudinal design to better track changes in student attitudes and behaviours within a BL context, as well as using extended representative sampling techniques to enhance the generalizability of findings. Further avenues for exploration could include investigating other influential variables, such as self-regulation, technology acceptance or learning engagement, as potential factors that contribute to the success of BL in fostering student learning satisfaction.

Disclosure statement

No potential conflict of interest was reported by the authors. [AQ4](#)

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The impact of blended learning on knowledge, skills and satisfaction in mathematics: a study in Indonesian universities

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The impact of blended learning on knowledge, skills and satisfaction in mathematics: a study in Indonesian universities

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ABSTRACT

Q2 Blended learning, a method that combines face-to-face and online instruction, has had a significant impact on higher education due to the rapid advancement of information and communication technology. This study analysed the effect of blended learning on students' knowledge, skills and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Squares (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study offers valuable insights for optimising curriculum design in higher education to enhance the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

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Introduction

The rapid evolution of information and communication technology (ICT) has profoundly reshaped operational paradigms across various institutions, with higher education undergoing a significant transformation (Abdi et al., 2025). Global data indicate a widespread adoption of technology, impacting multiple sectors, including education (Tamphu et al., 2024). This pervasive integration facilitates a learning ecosystem that transcends traditional boundaries of time and location. In higher education, technology has become integral to the learning process, empowering students to access course materials and engage in discussions with both instructors and peers online, thereby diminishing their reliance on the physical classroom as the sole learning environment (Alshurideh et al., 2023). This paradigm shift underscores technology's pivotal role in fostering a more dynamic and adaptive learning culture.

The surge in online learning was notably accelerated by the COVID-19 pandemic, which necessitated the closure of educational institutions worldwide and the abrupt shift to remote instruction (Gal & Geiger, 2022; Metaferia et al., 2023). While the pandemic subsided in 2021, enabling the resumption of face-to-face learning, including in Indonesia (Park et al., 2023), the integration of online learning systems within universities has persisted. Students often prefer online learning due to its perceived time-saving benefits and enhanced personal focus (Dolenc & Brumen, 2024). This enduring preference has fostered a new educational culture in Indonesia, characterised by a combination of face-to-face and online learning, commonly known as blended learning (BL) (Dwi Lestari & Riatur, 2024; Hill & Smith, 2023).

BL, a hybrid system that integrates face-to-face and online or distance learning, offers flexibility that aligns with student needs, enabling more effective time management and a more conducive study environment (Al-Mekhlafi et al., 2025). In Indonesia, several universities have significantly adopted BL

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environments, with some reaching up to 80% implementation (Prahmana et al., 2021). However, a recognised challenge within BL, particularly in mathematics instruction, lies in the subject's inherent 'higher level of complexity' (Alonso et al., 2025). Students frequently encounter difficulties comprehending digitally delivered mathematics content (Cho & Kim, 2020). The successful implementation of BL hinges on universities' ability to integrate it with their academic policies seamlessly (Buhl-Wiggers et al., 2023). When universities meticulously design curricula to integrate mathematics learning within a blended framework, it can significantly enhance student learning satisfaction and foster the development of both academic and non-academic skills.

Conversely, Hill and Smith (2023) emphasised that the success of a BL system is contingent upon the students' foundational knowledge. Students' ability to effectively integrate the mathematics learning system with BL methods within their academic environment is directly related to their existing knowledge (Awajan et al., 2024). This encompasses their technological proficiency, as students lacking adequate digital skills may face barriers in accessing materials, which can diminish their overall satisfaction with the mathematics learning process (Mullen et al., 2025).

Prior research has investigated the impact of BL on student satisfaction across diverse geographical contexts, including Australia with McCarthy et al. (2025), China with Wu (2024) and Ghana with Bervell and Umar (2020). These studies consistently reported a significant positive influence of BL on student learning satisfaction in these regions. Studies on BL in mathematics have shown that it can improve mathematical thinking skills, foster positive perceptions, enhance learning outcomes and increase self-regulation and problem-solving abilities (Ali, 2024; Awajan et al., 2024; Hill & Smith, 2023; Kyei-Akuoko et al., 2025; Mullen et al., 2025; Sanusi, 2022).

Specifically, within the Indonesian context, research about BL has predominantly focused on factors such as character, attitude, environment, social factors and usage intentions (Dwi Lestari & Riatun, 2024; Prahmana et al., 2021). Furthermore, as noted by Mullen et al. (2025), the efficacy of BL in mathematics instruction remains a subject of considerable debate. Therefore, a significant research gap exists regarding the specific impact of BL on student satisfaction in mathematics learning within Indonesia, particularly concerning the mediating roles of knowledge and skills. This study aims to address a critical gap by exploring factors that influence student satisfaction in the mathematics learning system in Indonesia, particularly given the limited research on these specific factors in recent years. The Indonesian context is particularly pertinent due to its vast and diverse higher education landscape, ongoing digital transformation initiatives and unique cultural approaches to education, which may influence the dynamics of BL adoption and its outcomes. Indonesia's commitment to improving its PISA scores in mathematics, which have historically been low (Gildore et al., 2025). Makes understanding practical pedagogical approaches, such as BL, particularly crucial in this context.

Building upon the assertions of Prifti (2022) and Al-Mekhlafi et al. (2025), which highlight the dependence of BL success on students' knowledge and expertise, this research posits knowledge and skills as mediating factors. The study aims to investigate whether robust knowledge and relevant skills influence Indonesian students' satisfaction with mathematics learning when adopting the BL method. This research is anticipated to serve as a vital reference for educational institutions, enabling them to comprehend the factors influencing student satisfaction in blended mathematics learning. Such insights will facilitate the adjustment of learning methods to better align with student needs and foster a more active academic environment that embraces technology in teaching and learning, especially in mathematics.

Theoretical framework

Blended learning

According to Alonso et al. (2025), BL is an educational system that effectively combines face-to-face instruction with flexible, independent online learning, leveraging digital technology. This system offers significant convenience in terms of time, place and learning methods, allowing students to access materials more flexibly (Uz & Uzun, 2018). The flexibility is particularly beneficial for university students, who often manage demanding schedules that encompass both academic and extracurricular

commitments. Buhl-Wiggers et al. (2023) noted that BL empowers students with direct instruction from lecturers in class and access to rich digital resources such as videos, interactive modules and online discussion forums, which are highly valuable even in mathematics learning. Students who are comfortable with technology and adept at independent learning tend to report higher satisfaction due to their ability to control their independent learning trend to report higher satisfaction due to their ability to control their learning pace (Tubagus et al., 2020). However, this system also inherently demands a higher level of students' discipline and responsibility (Xu et al., 2023). When coupled with adequate institutional support and a well-designed curriculum, implementing BL can significantly enhance the quality of the learning experience and foster greater student satisfaction (Sukkamart et al., 2025; Višňovská & Cortina, 2025).

The impact of BL on student learning satisfaction has been consistently noted. As mentioned, students' comfort with technology and capacity for independent learning often correlate with increased satisfaction, given their enhanced control over their learning rhythm (Rasheed et al., 2020). Furthermore, students' foundational knowledge of basic concepts critically influences the effectiveness of their engagement with BL (Li et al., 2022). Lazarevic and Bentz (2021) highlight that students with strong knowledge of the subject matter are better equipped to access, comprehend and apply information presented online and face-to-face. This foundational knowledge also encompasses students' expertise in leveraging technology to ensure success within the BL environment (Rasheed et al., 2020). Essential skills such as digital literacy, managing technological devices and effective communication are crucial. Students proficient in technological skills exhibit greater adaptability to the BL system, overcoming potential challenges and significantly enhancing their overall learning satisfaction (Engelbrecht & Borba, 2024).

Blended learning and knowledge

Knowledge, as defined by Gayed (2025), is the accumulation of information, facts, skills and understanding acquired through individual experience and education. Broadly, knowledge can be categorised into declarative knowledge (of facts and concepts) and procedural knowledge (of how to perform tasks) (Barbieri & Booth, 2020). Knowledge forms the primary foundation for effective learning in education, especially in mathematics. By integrating face-to-face and online methods, BL can influence and enrich students' mathematical knowledge (Liebendörfer et al., 2023). This model provides wider access to diverse digital information sources, including learning videos and discussion forums, thereby supporting the enrichment of students' declarative knowledge (Mullen et al., 2025). Moreover, the inherent flexibility of BL empowers students to manage their study time and location according to their individual needs, fostering independent exploration of the material (Kyei-Akuoko et al., 2025). Through online accessible learning, students engage with core mathematical concepts and participate in practical applications that reinforce their holistic understanding.

Several prior studies corroborate the positive effect of BL on knowledge acquisition. For instance, Liebendörfer et al. (2023) demonstrated that BL effectively improved nursing students' knowledge, facilitating better knowledge acquisition and task completion. Similarly, Al-Mekhlafi et al. (2025) found that BL enhanced the public health knowledge of students in Korea, attributing this to easier access to materials and the ability to review challenging sections outside of class time. Kyei-Akuoko et al. (2025) further supported this, suggesting that BL can increase student knowledge by minimising fatigue and enhancing focus. Based on these consistent findings, it is hypothesised that:

H1: Blended Learning (BL) positively affects student knowledge in mathematics learning in Indonesia.

Blended learning and skill

As defined by Sukkamart et al. (2025), it refers to an individual's ability to perform specific tasks or jobs proficiently and efficiently. Skills can encompass cognitive, technical, social or managerial competencies developed through continuous learning and experience (Liu & Yushchik, 2024). Within the educational

context, student skills pertinent to BL in mathematics include critical thinking, problem-solving, communication and technical proficiency (Al-Mekhlafi et al., 2025). BL uniquely offers students opportunities to apply their mathematical knowledge through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Kyei-Akuoko et al., 2025). Engelbrecht and Borba (2024). Furthermore, it is highlighted that integrating technology in learning facilitates cross-geographic collaboration via online platforms, fostering the development of broader communication and teamwork skills. Thus, beyond offering flexibility, BL cultivates a rich environment for developing essential mathematical skills in students.

Empirical evidence supports the positive impact of BL on skill development. Moradimokhles and Hwang (2022) found that BL significantly improved students' English language skills. Li et al. (2019) similarly reported that BL substantially enhanced the skills of nursing students, attributing this to the flexibility it provides for students to access materials at their own pace and according to their learning style. Chaeruman et al. (2020) also confirmed that BL significantly influenced skills in clinical supervisor training, noting its higher efficiency. Based on these findings, it is hypothesised that:

H2: Blended Learning (BL) positively affects student skills in learning mathematics in Indonesia.

Knowledge and skill

Knowledge is fundamental to students' mathematics learning process, forming the bedrock for developing more complex skills (Espinoza-Vásquez et al., 2025). In an academic setting, knowledge directly influences how students approach problem-solving, make informed decisions and cultivate professional-level skills (Yang et al., 2022). The critical importance of knowledge lies in its transformative ability to shape skills. A solid knowledge base empowers students to grasp mathematical concepts in depth and effectively apply that understanding to practical situations (Quintos et al., 2025). Furthermore, contemporary education emphasises skills beyond mere cognitive knowledge, expecting students to possess strong problem-solving, critical thinking and adaptive skills to navigate the dynamic changes in mathematics learning (Aoki et al., 2025).

Additionally, robust knowledge enables students to access diverse perspectives, enriching their critical and innovative thinking skills. Thus, knowledge is not merely a passive repository but an active resource that drives innovative skills and effective problem-solving (Franco & DeLuca, 2019). Research consistently demonstrates this relationship. Murillo-Zamorano and Montanero (2018) found that knowledge significantly influences students' skills in using flipped classrooms. Alfian et al. (2024) further substantiated this, reporting a significant impact of knowledge on students' listening and reading comprehension skills. (Murillo-Zamorano & Montanero, 2018) also reinforced this by showing that students' knowledge capacity positively affects their oral presentation skills. Given these established links, it is hypothesised that:

H3: Blended Learning (BL) positively affects students' knowledge in mathematics learning in Indonesia.

Knowledge and learning satisfaction

Knowledge is the primary foundation that influences how students comprehend mathematical material and apply it in various contexts (Ibrahim & Alhosani, 2020). In mathematics, this knowledge extends beyond mere facts and theories to encompass the critical analysis abilities needed to interpret information (Barbieri & Booth, 2020). The deeper and more critical a student understands a concept, the greater their satisfaction in studying mathematics (Krawitz et al., 2025). In this context, student learning satisfaction refers to the level of pleasure and contentment students derive from their mathematics learning experience (Wong & Chapman, 2023). This satisfaction is intrinsically linked to how the knowledge acquired impacts their learning journey (Akbar et al., 2025). Students with profound mathematical knowledge are better equipped to assimilate new material, leading to higher satisfaction. Conversely, a lack

of knowledge can lead to confusion, frustration and decreased motivation, ultimately reducing their satisfaction with mathematics learning (Haghighat et al., 2023). Therefore, knowledge is crucial in fostering a positive mathematics learning experience and promoting optimal academic achievement for students.

Prior studies consistently affirm that knowledge influences satisfaction. Haghighat et al. (2023) found that knowledge has a positive impact on learning satisfaction among nursing students. Murillo-Zamorano and Montanero (2018) similarly observe that knowledge significantly influenced students' learning satisfaction in the flipped classroom, mainly because students were required to engage with the material before face-to-face sessions, forming a foundational understanding for discussions. Abuhassna et al. (2020) also emphasised that the quality of knowledge directly affects learning satisfaction in both undergraduate and postgraduate students, enabling them to achieve their academic goals more effectively. Based on these findings, it is hypothesised that:

H4: Knowledge positively affects the mathematics learning satisfaction of students in Indonesia.

Skill and learning satisfaction

Skills represent an individual's learned and experienced abilities, enabling them to perform specific tasks effectively (Smith, 2022). In higher education mathematics, students' foundational skills are crucial to their ability to absorb and apply material effectively in practical situations (Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022)(Zagouras et al., 2022). Students who perceive themselves as possessing adequate skills tend to exhibit greater confidence, which enhances their ability to understand mathematical material deeply and fosters a sense of self-satisfaction (Alonso et al., 2025). For example, Murillo-Zamorano and Montanero (2018) reported that students' expertise in utilising flipped classrooms significantly affected their learning satisfaction. This is because students proficient in independent learning and time management skills are better equipped to effectively leverage the flipped classroom model. Yoo and Cho (2020) further demonstrated that skills can lead to higher learning satisfaction within the flipped classroom system, given its perceived efficiency in terms of time and place, allowing students to tailor their learning style. Based on these preceding findings, it is hypothesised that:

H5: Skill positively affects the mathematics learning of students in Indonesia.

Blended learning, knowledge and learning satisfaction

BL, as an instructional method that integrates face-to-face and online components, offers a flexible approach that accommodates diverse student learning styles and fosters deeper knowledge acquisition (Yehia et al., 2022). In supporting mathematics learning, the blended approach enables students to access information independently and flexibly, thereby profoundly increasing their in-depth knowledge. The broader access to materials afforded by BL also facilitates their mathematical exploration of subjects of interest (Okai-Ugbaje et al., 2020). Enhanced knowledge, in turn, strengthens conceptual understanding in applying BL methods and boosts students' confidence in mastering mathematical knowledge due to BL. It is expected to increase their overall learning satisfaction and encourage continuous engagement (Al-Mekhlafi et al., 2025).

Previous research provides empirical support for this mediated relationship. Adi and Fathoni (2020) demonstrated that BL effectively improved nursing students' knowledge. Similarly, Julia et al. (2020) found that BL enhanced the knowledge of public health students in Korea, attributing this to easier material access and the ability to review difficult content outside of class time. Shimizu and Kang (2025) also noted that BL directly influenced learning satisfaction for these students. Furthermore, Roos and Bagger (2024) confirmed that knowledge impacts learning satisfaction in nursing students. Murillo-Zamorano and Montanero (2018) reinforced this by finding that knowledge significantly affected student learning satisfaction in flipped classrooms. Critically, Sojayapan and Khlaisang (2018) specifically

highlighted that flipped classrooms could influence student learning satisfaction mediated by knowledge. Synthesising these findings, it is hypothesised that:

H6: Blended learning affects student mathematics learning satisfaction in Indonesia, Mediated by Knowledge.

Blended learning and skill and learning satisfaction

Developing expertise and technological skills is often promoted through blended learning (BL (Zagouras et al., 2022). By utilising BL, students are trained to manage assignment deadlines independently, thereby improving essential self-management skills, which are particularly crucial in mathematics learning due to its often higher level of complexity. Studies have shown a positive impact of BL on skills (Chaeruman et al., 2020). Moradimokhles and Hwang (2022) found that BL influenced students' English language skills in clinical supervisor training attributing its effectiveness to higher efficiency.

Additionally, Fisher et al. (2021) demonstrated that BL positively influences student learning satisfaction in Australian universities. This is often because the blended methods allow students to access materials at any time, facilitating an adjustment of the learning process to their individual needs. Crucially, skill plays a vital role in supporting learning satisfaction. Murillo-Zamorano and Montanero (2018) explained that students' expertise in flipped classrooms can significantly influence their learning satisfaction, as skilled students are better prepared to utilise this learning model effectively. Maarif et al. (2022) also showed that skills lead to higher learning satisfaction in the flipped classroom system. Integrating these insights, it is hypothesised that:

H7: Blended Learning (BL) affects students' mathematics learning satisfaction in Indonesia, mediated by skill.

Blended learning and knowledge and skills

By combining face-to-face instruction with online learning elements, **BL** offers inherent flexibility that enhances student knowledge and facilitates learner interaction (Tubagus et al., 2020). In mathematics, **BL** enables students to learn fundamental concepts independently through digital resources while utilising face-to-face sessions to deepen their understanding of more complex topics (Mullen et al., 2025). The knowledge acquired through such independent learning not only aids students in grasping theoretical concepts but also cultivates vital analytical and problem-solving skills essential for mathematics learning. Empirical evidence supports this link: Wawro and Serbin (2025) showed that **BL** effectively improved nursing students' knowledge. Alonso et al. (2025) also highlighted that **BL** provided easier access to materials, enabling students to repeatedly review difficult sections outside of class to deepen their understanding.

Furthermore, research indicates a direct link between **BL** and skills and knowledge. Roos and Bagger (2024) stated that **BL** influenced students' skills in nursing education, attributing this to the flexibility that allows self-paced learning combined with direct lecturer supervision for practical skill perfection. More specifically, Altas and Mede (2020) found that knowledge significantly influenced students' skills in using flipped classrooms. Hankeln and Prediger (2025) also clarified that knowledge impacts students' listening and reading skills. Given these sequential relationships, it is hypothesised that:

H8: Blended Learning affects students' mathematics learning skills in Indonesia through the mediation of knowledge.

Knowledge, skill and learning satisfaction

Knowledge is the cornerstone of the learning process, particularly in complex disciplines such as mathematics (Gildore et al., 2025). It enables students to comprehend theory and effectively utilise their skills

in solving more challenging mathematical problems (Manson & Ayres, 2021). Strong knowledge is, therefore, expected to enhance students' skills, which, in turn, will significantly contribute to their learning satisfaction. Students with robust knowledge tend to develop more effective skills, which directly enhance their process (Strohmaier et al., 2020). Consequently, the synergistic presence of knowledge and skills is anticipated to facilitate a more meaningful mathematics learning experience, leading to higher levels of student satisfaction (Gurmu et al., 2024).

Various studies support this mediated relationship. Pongsakdi et al. (2020) demonstrated a significant influence of knowledge on students' listening and reading comprehension skills. Geiger et al. (2023) similarly showed that students' knowledge capacity positively affected their oral presentation skills, as good knowledge often correlates with increased confidence in conveying information and structuring ideas.

Furthermore, Zhang et al. (2021) found that knowledge influenced learning satisfaction in nursing students, emphasising its critical role in creating an optimal mathematics learning experience for academic achievement. On the other hand, Murillo-Zamorano and Montanero (2018) the study explained that students' expertise in the flipped classroom significantly influenced their learning satisfaction, as skilled students are better prepared for face-to-face sessions due to their foundational independent learning. Shlomo and Rosenberg-Kima (2025) also reinforced that skills lead to higher learning satisfaction in the flipped classroom system. Based on these cumulative findings, it is hypothesised that:

H9: Knowledge influences the learning satisfaction of mathematics students in Indonesia through Skill mediation.

Research methodology

This study employed a quantitative survey methodology to collect data. The survey was conducted online to gather information from university students across Indonesia who had prior experience with blended learning (BL) in mathematics. A *snowball sampling* method was utilised to recruit participants. This approach involved initially recruiting respondents through social networks, who then referred to other relevant individuals from their contacts. This technique was chosen due to its practicality in accessing specialised and geographically dispersed populations of students engaged in blended mathematics learning. However, it is crucial to acknowledge that the effectiveness and efficiency of snowball sampling are largely contingent on the personal and professional networks of the researcher (Iska et al., 2023). Furthermore, the reliance on self-referral in snowball sampling reduces the sample's representativeness of the findings to the broader student population in Indonesia. This lack of control over the sampling process means the sample may exhibit a degree of homogeneity, potentially overlooking diverse perspectives outside the initially engaged networks (Siri et al., 2020).

The questionnaire was structured into several distinct sections. It began with demographic inquiries, such as age, gender and education level, and subsequently posed questions about respondents' experience with the BL method for mathematics. The online format of the survey ensured broad reach and convenient access for participants. A total of 304 students' responses were collected and deemed eligible for analysis, encompassing diverse demographics regarding gender, education level and gadget usage across various islands in Indonesia (See Table 1 for detailed sample characteristics).

The core variables measured in this study included Blended Learning (BL), Knowledge (KN), Skill (SK) and Learning Satisfaction (LS). Each variable was assessed using a 5-point Likert scale, ranging from 1 ('strongly disagree') to 5 ('strongly agree'), to gauge respondents' perceptions across the various dimensions investigated. This 5-point scale was specifically chosen for its widespread use and familiarity in educational research, which enhances comparability. Its balanced structure provides sufficient nuance without overwhelming respondents (Riyadh et al., 2019). While acknowledging the ordinal nature of Likert scale data, it is a common practice in PLS-SEM to treat such data as suitable for path analysis, given its non-parametric algorithm and robustness (Hair et al., 2023). A detailed description of each variable and its measurement is provided below:

Table 1. Demographic respondents.

Variable	Demographic	Total	Percentage
Gender	Male	142	46.71
	Female	162	53.29
Island	Sumatera	45	14.80
	Java	142	46.71
	Kalimantan	76	25.00
	Sulawesi	41	13.49
Level of education	Undergraduate Degree	221	72.70
	Postgraduate Degree	52	17.11
	Doctoral Degree	31	10.20
Gadgets most often used for studying	Smartphone	129	42.43
	Tablet	21	6.91
	Computer	33	10.86
	Laptop	121	39.80

- **Blended Learning (BL):** This construct measures the perceived effectiveness of BL in the educational context, encompassing aspects such as time flexibility, ease of material access and the seamless integration of online and face-to-face learning components. The measurement items for BL were adapted from established instruments by Birbal et al. (2018) and Yehia et al. (2022).
- **Knowledge (KN):** This variable assessed students' depth of understanding regarding mathematical concepts delivered through BL. The questions aimed to evaluate conceptual clarity, comprehension of presented material and the ability to apply theoretical knowledge effectively. KN measurement items were adapted from previous studies, notably (Murillo-Zamorano & Montanero, 2018).
- **Skill (SK):** This construct focuses on students' proficiency in solving mathematical problems and their adeptness in utilising the tools and resources available on the BL platform. Relevant items included analytical skills, problem-solving capabilities and applying acquired knowledge in practical situations. Murillo-Zamorano and Montanero (2018) adapted SK measurement items from prior research.
- **Learning Satisfaction (LS):** This variable measures a student's overall satisfaction with their learning experience. It specifically included items evaluating satisfaction with the BL methodology, the teaching efficacy of lecturers and the perceived growth in their knowledge and skills. The LS measurement items were adapted from previous studies by Huang (2021) and Sun et al. (2008).

Data analysis was performed using the Structural Equation Model - Partial Least Squares (SEM-PLS) method. This approach was chosen for its suitability in handling complex research models with multiple independent, mediating and dependent variables, its strong emphasis on predictive power by maximising variance explained in endogenous constructs, and its fewer assumptions regarding data distribution, which is beneficial for data collected via Likert scales (Hair et al., 2023; Henseler et al., 2016). The analysis proceeded in two principal stages, adhering to the recommendations put forth by Hair et al. (2023), Henseler et al. (2016) and Rigdon et al. (2017).

The initial stage involved the Evaluation of the Measurement Model, which was crucial for establishing the reliability and construct validity of research variables: Blended Learning, Knowledge, Skill and Learning Satisfaction. This phase ensured that each construct was consistently and accurately measured. Specifically, reliability was assessed through internal consistency using Cronbach's Alpha (α) and Composite Reliability (CR). Validity was established by examining convergent validity (using Average Variance Extracted [AVE] values and indicator outer loadings) and discriminant validity (using the Heterotrait-Monotrait Ratio [HTMT] criterion). Additionally, content validity was ensured through expert review of the questionnaire items to confirm their relevance and comprehensiveness (as noted in the instrument description).

Following the successful validation of the measurement model, the subsequent stage involved evaluating the Structural Model. This phase focused on testing the hypothesised relationships between the identified latent variables. Path analysis examined both direct and indirect effects among these variables. To robustly assess the significance of these direct and indirect paths, a bootstrap resampling technique with 5,000 samples was employed. This approach yields a more robust estimation of standard errors,

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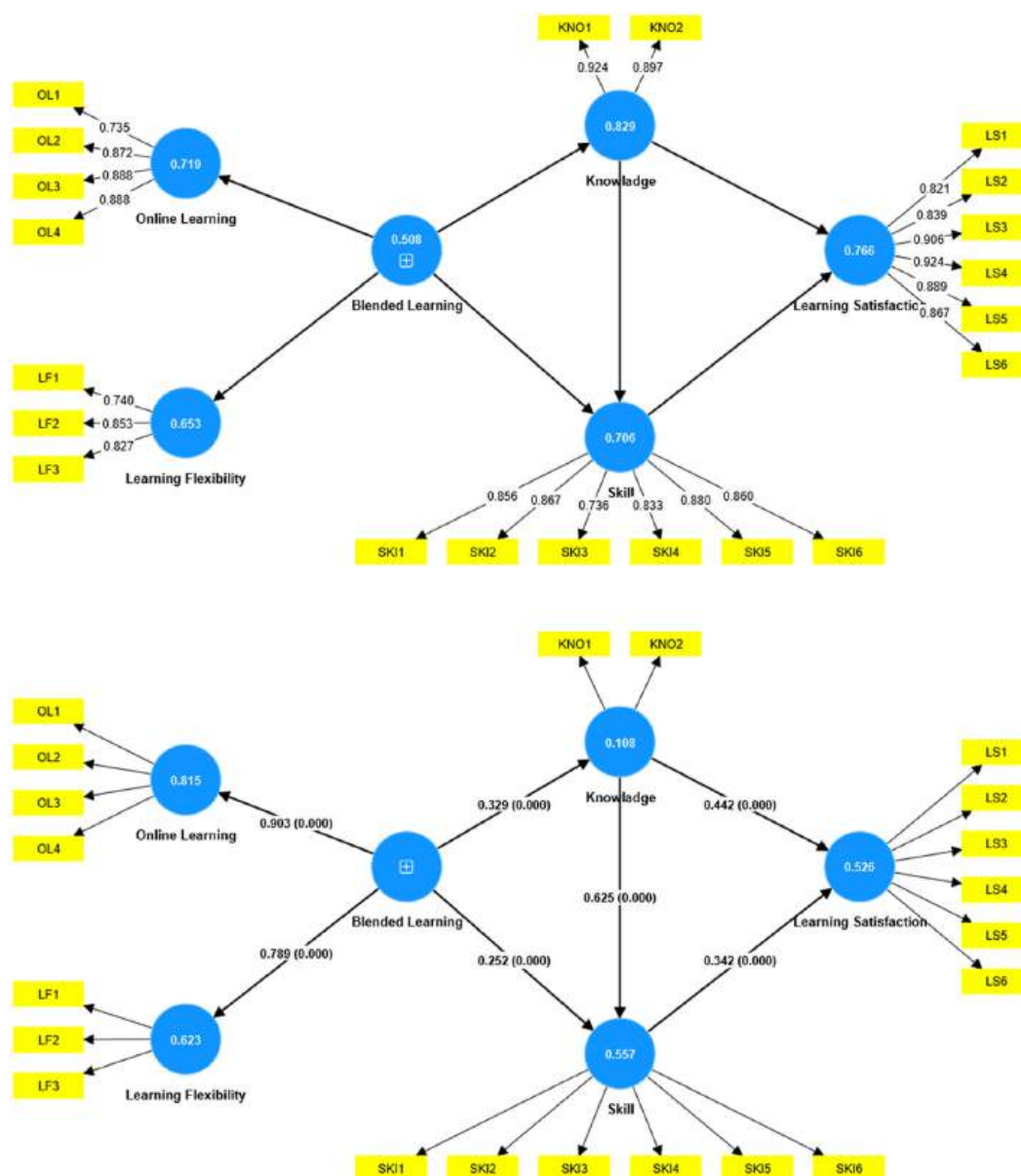


Figure 1. Outer and inner model.

thereby providing a more precise determination of the statistical significance of the effects observed between variables.

Results and discussions

This section presents the findings derived from the statistical analysis, specifically focusing on the evaluation of the measurement model and the structural model. We detail the outcomes of our investigation into the hypothesized relationships between the identified latent variables, followed by a comprehensive discussion that interprets these results in the context of existing literature and their implication for mathematics education (Figure 1).

Evaluation measurement model

Before proceeding with hypothesis testing, a rigorous evaluation of the measurement model was conducted to establish the reliability and validity of all constructs. This critical step encompassed

assessments of indicator reliability, internal consistency reliability, convergent validity and discriminant validity, adhering to the established guidelines outlined by Hair et al. (2023).

Indicator reliability

Indicator reliability was initially assessed by examining the outer loading (OL) values. These values quantify the extent to which the variance of each indicator is explained by its underlying construct, thereby reflecting the reliability of the indicator. The widely accepted recommendation for outer loading values is greater than 0.70. As presented in Table 2, all outer loading values in this study surpassed this threshold, confirming that the indicator reliability for all constructs has been robustly met.

Internal consistency reliability

Cronbach's Alpha (α) and Composite Reliability (CR) were evaluated to ascertain the internal consistency reliability. These metrics are crucial for determining the degree to which indicators designed to measure the same latent construct are intercorrelated and consistent. As shown in Table 2, both the Cronbach's Alpha and Composite Reliability values for all constructs exceeded 0.70. This outcome indicates that the indicators employed in this study are internally consistent and can, therefore, be considered as reliable, fully aligning with the recommendations provided by Hair et al. (2023).

Convergent validity

Convergent validity was assessed through the Average Variance Extracted (AVE). The AVE value indicates the variance a construct explains in its indicators relative to the amount of variance due to measurement error. A high AVE value signifies that all items within a construct converge well, collectively explaining a substantial portion of their shared variance. Manley et al. (2021) recommend an AVE value of 0.50 or higher. As evidenced in Table 2, all AVE values in this study were greater than 0.50, thus confirming the convergent validity of all constructs.

Discriminant validity

Discriminant Validity was examined to ensure that each construct is empirically distinct and sufficiently differentiated from other constructs within the structural model. Henseler et al. (2015) recommend

Table 2. Outer loading and convergent validity.

Variable	Item	OL	α	CR	AVE
Knowledge	KNO 1	0.924	0.795	0.907	0.829
	KNO 2	0.897			
Blended learning	Online learning	0.789	0.834	0.877	0.508
	Learning flexibility	0.903			
Learning flexibility	LF 1	0.740	0.938	0.951	0.766
	LF 2	0.853			
	LF 3	0.827			
Online learning	OL 1	0.735	0.916	0.935	0.706
	OL 2	0.872			
	OL 3	0.888			
	OL 4	0.888			
Learning satisfaction	LS 1	0.821	0.938	0.951	0.766
	LS 2	0.839			
	LS 3	0.906			
	LS 4	0.924			
	LS 5	0.889			
	LS 6	0.867			
Skill	SKI 1	0.856	0.916	0.935	0.706
	SKI 2	0.867			
	SKI 3	0.736			
	SKI 4	0.833			
	SKI 5	0.880			
	SKI 6	0.860			

Notes: OL = Outer Loading, CR = Composite Reliability, AVE = Average Variance Extracted.

Table 3. Discriminant validity

	Blended learning	Knowledge	Learning satisfaction	Skill
Blended learning				
Knowledge	0.400			
Learning satisfaction	0.477	0.785		
Skill	0.526	0.827	0.705	

Table 4. Path coefficients, effect size and collinearity test.

	β	T-stats	P-values	VIF	f2
BL -> KNO	0.329	5.529	0.000	1.000	0.122
BL -> SKI	0.252	6.032	0.000	1.122	0.128
KNO -> LS	0.442	7.186	0.000	2.003	0.206
KNO -> SKI	0.625	14.792	0.000	1.122	0.786
SKI -> LS	0.342	4.985	0.000	2.003	0.123
BL -> KNO -> LS	0.145	4.272	0.000	–	–
BL -> KNO -> SKI	0.206	5.290	0.000	–	–
BL -> SKI -> LS	0.086	3.669	0.000	–	–
KNO -> SKI -> LS	0.214	4.777	0.000	–	–

utilizing the Heterotrait-Monotrait (HTMT) for a more robust discriminant validity assessment, with a recommended threshold value below 0.90. Based on the results presented in Table 3, all HTMT values were below 0.90. This outcome unequivocally indicates that discriminant validity has been established for all constructs, rendering them suitable for subsequent analysis within the structural model.

Evaluation of the structural model

Hypothesis testing was conducted by analysing the path coefficients and their statistical significance. This was achieved through a robust bootstrapping procedure involving 5000 resamples with a 95% bootstrap confidence level, as Henseler et al. (2016) recommended. The results for each hypothesised path are presented in detail below and are summarised comprehensively in Table 4.

H1: Blended Learning (->) knowledge ($\beta = 0.329$, T-stat 5.529, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Knowledge (KN)** is **positive and significant**, thus providing strong support for **H1**. This finding robustly indicates that the strategic implementation of BL notably enhances students' knowledge acquisition. This result is consistent with the extant literature, particularly Al-Mekhlafi et al. (2025), which posits that BL facilitates easier access for students to revisit challenging material, thereby deepening their comprehension of complex mathematical concepts. The inherent flexibility of BL, which allows students to learn at their own pace, is profoundly important in mathematics. This subject often demands extensive time and repeated exposure to grasp abstract concepts.

Furthermore, the expensive access to diverse digital resources, such as interactive modules and video tutorials, empowers students to explore various cognitive pathways to internalise complex mathematical ideas. Liebendörfer et al. (2023) underscored that the BL methodology can significantly augment student engagement and motivation, particularly for demanding subjects like mathematics, owing to its adaptable learning styles. This finding aligns with research indicating that knowledge acquired through BL transcends mere theoretical understanding, encompassing the ability to apply concepts in broader contexts.

H2: Blended Learning (->) skill ($\beta = 0.252$, T-stat = 6.032, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Skill (SK)** is also **positive and significant**, confirming the acceptance of **H2**. This underscores that BL effectively contributes to the development of students' mathematical skills. Sukkamart et al. (2025) emphasise the critical role of skills in technology-enhanced learning environments, where BL uniquely enables students to hone the technical and analytical proficiencies indispensable for solving complex mathematical problems. The strategic integration of technology within the learning process, including online discussion forums and computer-based practice exercises, provides invaluable opportunities for students to practice and apply their mathematical knowledge in practical situations actively. This finding resonates strongly with Dwi Lestari and Riatun (2024), who demonstrated that BL substantially increases students' skills by fostering independent learning and the flexible

application of relevant abilities across diverse scenarios. In mathematics, BL is instrumental in helping students practice problem-solving as frequently as needed to solidify their understanding.

H3: Knowledge (->) Skill ($\beta = 0.625$, T-stat = 14.792, $p < 0.001$) The path from **Knowledge (KN)** to **Skill (SK)** exhibits a powerful positive and significant, profoundly indicating that higher levels of knowledge lead to significant improvements in with the pedagogical principle that a solid and deep knowledge base forms the essential foundation for cultivating higher-order skills, particularly in complex subjects such as mathematics. In mathematics education, an in-depth understanding of theoretical concepts provides students with a robust framework to apply their comprehension in practical contexts, including rigorous problem-solving and comprehensive analysis. According to Sanusi (2022), the knowledge acquired through blended learning, it empowers students to enhance their problem-solving capabilities by providing access to diverse digital resources that facilitate a deeper conceptual understanding. With a firm theoretical grasp, students are better prepared to apply their knowledge in real-world scenarios, which, in turn, sharpens their critical and analytical thinking skills. Moreover, Xu et al. (2023) highlighted that declarative knowledge (factual and conceptual understanding) frequently serves as the indispensable precursor for the development of procedural skills (the 'how-to' aspect of problem-solving), both of which are paramount in mathematics learning. Students with strong declarative knowledge are better equipped to develop procedural skills, such as solving complex equations or intricate problems, which facilitates the emergence of more sophisticated skills, including critical thinking and advanced problem-solving abilities. Within the BL context, students can strategically utilise various online materials to reinforce their foundational knowledge, subsequently applying that knowledge in practice questions or collaborative disciplines that demand high-level problem-solving skills.

H4: Knowledge (->) Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186, $p < 0.001$) The relationship between **Knowledge (KN)** and **Learning Satisfaction (LS)** demonstrates strong **positive and significant effect**, suggesting that students who possess greater knowledge exhibit higher satisfaction with their learning experience. This supports **H4**. The acquisition of knowledge during the learning process has a significant and direct impact on learning satisfaction. This suggests that *students with sufficient knowledge are generally more satisfied* with their learning experience. This finding is entirely consistent with research Alrajhi (2024), which indicates that increased knowledge during the learning process contributes to elevated learning satisfaction, particularly when students feel empowered to apply their acquired knowledge in a practical context. In mathematics education, learning satisfaction is frequently correlated with how thoroughly students grasp the concepts taught and their demonstrable ability to solve related problems. When students perceive that they gain a deep understanding of mathematical topics through BL, their satisfaction with the learning process markedly increases as they feel more prepared and confident in navigating academic challenges.

H5: Skill (->) Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985, $p < 0.001$). The effect of **Skill (SK)** on **Learning Satisfaction (LS)** is also **significant and positive**, implying that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, **H5 is supported**. This study found that the skills students acquired during their learning journey significantly contributed to their overall learning satisfaction. Brandsæter and Berge (2025) articulated that students with superior skills in utilising learning technology typically report higher satisfaction with their learning process, primarily because they feel more capable of solving problems and effectively managing their independent learning. In the domain of mathematics education, skills cultivated through BL, such as analytical thinking and problem-solving capabilities, instil greater self-confidence in students, which ultimately translates into increased satisfaction. Students who perceive they have developed competencies relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they can discern the practical applications of their newly acquired knowledge. This finding is further reinforced by Fan et al. (2022), which states that skills developed through technology-based learning substantially increase student satisfaction, as these skills better equip them to confront challenges in real-world challenges.

Indirect effects (mediation analysis)

The study also thoroughly investigated the *indirect effects* to ascertain the crucial mediating roles of *Knowledge* and *Skill* within the hypothesised relationships.

H6: Blended Learning (->) Knowledge (->) Learning Satisfaction ($\beta = 0.145$, T-stat = 4.272, $p < 0.001$) The indirect effects of BL on Learning Satisfaction **through Knowledge** are **significant**, providing clear support for **H6**. This mediation effect profoundly highlights the *important role of knowledge acquisition* in bridging the relationship between BL and students' learning satisfaction, especially in the context of mathematics. BL, with its integrated approach that combines online and face-to-face instruction, provides students with enhanced overall learning satisfaction.

H7: Blended Learning (->) Skill (->) Learning Satisfaction ($\beta = 0.086$, T-stat = 3.669, $p < 0.001$). The indirect effects of BL on Learning Satisfaction **through Skill** are also **significant**, although with a comparatively smaller effect size. This finding supports **H7**. This suggests that BL indirectly contributes to learning satisfaction by fostering the development of essential skills. As observed in this study, the acquisition of enhanced skills confers higher self-confidence on students, which, in turn, significantly enhances their satisfaction with the learning experience. Cevikbas and Kaiser (2023) demonstrated that students who feel proficient in utilising learning technology and are adept at applying mathematical concepts tend to be more satisfied with their learning process. In mathematics education, skills cultivated through BL, such as the ability to solve complex problems or fully utilise mathematical technology (e.g. graphing calculators, modelling software), play a pivotal role in increasing students' self-confidence. The more skilled students become in leveraging these tools, the more satisfied they are with their learning outcomes (Engelbrecht & Borba, 2024). This indirect effect illustrates that BL not only confers direct benefits in skill enhancement but also contributes to increased student learning satisfaction through the holistic development of these crucial skills.

H8: Blended Learning (->) Knowledge (->) Skill ($\beta = 0.206$, T-stat= 5.290, $p < 0.001$) The indirect effects of BL **through Knowledge** are **significant**, profoundly indicating that **knowledge** acts as a crucial mediator between BL experiences and subsequent skill development. This provides robust support for **H8**. Knowledge indeed serves as a potent mediator in the relationship between BL and skills. As highlighted in the seminal study by Sukkamart et al. (2025), a robust theoretical knowledge base often forms an indispensable foundation for the development of practical skills. In the context of mathematical education, students who possess a deep and nuanced understanding of mathematical theories are inherently better at applying this intricate knowledge in solving real-world problems, which demonstrably improves their skills. BL uniquely provides students with the opportunity to learn mathematics in diverse formats (such as comprehensive texts, engaging videos and interactive exercises), allowing them to learn in a manner that optimally suits their learning styles. The profound knowledge gained through this dynamic method then empowers students to develop superior skills in solving mathematical problems, both within the structured confines of the classroom and in broader, real-life contexts. Tran and O'Connor (2024) found that knowledge acquired through online learning contributed significantly to the development of practical skills in domains requiring deep conceptual understanding, including mathematics.

H9: Knowledge (->) Skill (->) Learning Satisfaction ($\beta = 0.214$, T-stat = 4.777, $p < 0.001$) The final mediation effect of knowledge on learning Satisfaction **through Skill** is **significant**, unequivocally indicating that **skills** act as a critical mediator between knowledge acquisition and learning satisfaction. This leads to the acceptance of **H9**. Students who cultivate a deep understanding of mathematical concepts are considerably more likely to effectively apply their knowledge in practical situations, which directly fosters superior skill development. Demir et al. (2022) found that declarative knowledge (theoretical understanding) frequently functions as an important foundation for the development of procedural skills (practical application). In mathematics education, strong theories of knowledge empower students to develop more sophisticated analytical and problem-solving skills, ultimately leading to increased learning satisfaction. Within the BL environment, the profound knowledge gained through various online resources enables students to actively practice and strengthen their skills in solving mathematical problems. These enhanced skills contribute to achieving better academic results and significantly increase students' satisfaction with the learning process, as they feel more prepared and competent to overcome academic challenges effectively.

Coefficients of determination (R^2)

The coefficients of determination (R^2) quantify the proportion of variance in the endogenous construct that the exogenous construct within the research model can explain. Hair et al. (2023) provide general

Table 5. Coefficient of determination.

	R-square	Adjusted R-square
Knowledge	0.108	0.106
Learning Satisfaction	0.526	0.523
Skill	0.557	0.554

guidelines, suggesting that R2 values of 0.25, 0.50 and 0.75 typically indicate weak, moderate and strong levels of explanatory power, respectively. As presented in Table 5, the Adjusted R2 values for this study demonstrate that the model effectively explains 52.3% of the variation in Learning Satisfaction and 55.4% of the variation in Skill. This suggests that the construct of BL, Knowledge and Skill, as conceptualised in this model, collectively exhibit a moderate to strong explanatory power over student learning satisfaction and skill development in mathematics.

Effect size (f^2)

Effect Size (f^2) is a crucial metric employed in SEM analysis to measure the substantive impact of an exogenous construct on an endogenous construct. This is achieved by calculating the R2 value after systematically removing one exogenous construct at a time (Hair et al., 2023). Li et al. (2022) established widely accepted benchmarks, categorising f^2 values of 0.02 as a small effect, 0.15 as a moderate effect, and 0.35 as a significant effect. For example, as detailed in Table 4, the effect of Knowledge on Skill ($f^2 = 0.786$) is substantial, unequivocally indicating a significant and profound contribution of knowledge to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also demonstrate moderate effects, further underscoring the critical importance of knowledge acquisition in shaping positive learning outcomes within an educational context.

Potential causes for variations from related studies

While the findings of this study broadly resonate with the growing body of literature on the benefits of BL, academic rigour demands an acknowledgement that research outcomes can exhibit variations across different studies. Such discrepancies are not uncommon and often stem from a confluence of interconnected factors. One primary contributor to these variations is BL's specific modality and implementation. The precise balance between online and face-to-face components, the specific digital tools and platforms employed, and the underlying pedagogical approaches adopted can differ significantly between studies (Alonso et al., 2025; Engelbrecht & Borba, 2024; Tubagus et al., 2020). For instance, a BL model that is heavily reliant on synchronous online discussions might yield different results than one that emphasises asynchronous interactive modules, leading to distinct impacts on student engagement and learning outcomes.

Furthermore, contextual factors play a profound role in shaping research findings. The cultural and educational landscape in which a study is conducted, including the specific characteristics of the Indonesian higher education system, unique student demographics, pre-existing levels of technological exposure and the prevailing digital infrastructure, can all profoundly influence how students perceive, adapt to and ultimately benefit from BL. These localised variables can create subtle yet significant differences in learning experiences compared to studies conducted in, for example, Western educational settings with different pedagogical traditions or access to technology, highlighting the importance of situated learning perspectives (Kyei-Akuoko et al., 2025). Similarly, discipline-specific nuances are also critical. While this study focused on mathematics, the effectiveness of BL and the precise mediating roles of knowledge and skill may vary across diverse academic disciplines, owing to inherent differences in subject matter complexity, distinct learning objectives and the unique cognitive skills required for mastery in each field (Liebendörfer et al., 2023).

Finally, variations can also arise from methodological differences, including the operationalisation and measurement of constructs such as 'Knowledge', 'Skill' and 'Learning Satisfaction'. Different measurement instruments or scales can capture distinct facets of these constructs, influencing the observed relationship (Engelbrecht & Borba, 2024). Additionally, the characteristics of the student samples, such as their

academic background, intrinsic motivation levels or prior digital literacy, while the sampling methodologies employed the use of non-probability sampling, which, as a limitation of this study, can impact generalizability, can lead to notable differences in findings when comparing across studies (Meikleham & Hugo, 2020). Acknowledging these potential sources of variation is fundamental for a nuanced interpretation of research findings and for advancing a more sophisticated understanding of BL's complex effectiveness across diverse educational landscapes.

Implications for higher education

The robust findings from this study offer a profound understanding and carry significant, actionable implications for educational institutions, particularly within the dynamic landscape of mathematics teaching in Indonesian higher education. Since BL has been demonstrably proven effective in significantly improving key student learning outcomes, specifically fostering deeper Knowledge acquisition and enhancing essential skills development (as evidenced by the current study's findings, consistent with broader trends noted by Abuhassna et al. (2020)—its strategic application and broader integration within higher education curricula should be a paramount priority for institutions.

Higher education institutions should consider several key focus areas to optimise the utilisation of these valuable research results. Firstly, there is a compelling need to prioritise and invest in developing highly interactive and contextually relevant digital content. This includes designing and providing a rich array of engaging online learning materials, such as sophisticated simulations, adaptive interactive exercises and meticulously produced high-quality video tutorials, all meticulously tailored to address the unique complexities of mathematical concepts (Strohmaier et al., 2020). Such a proactive approach will support diverse learning styles and empower students to achieve self-paced mastery, a critical component of deep learning in mathematics. Secondly, institutions must continue to strengthen and enhance their online learning platforms. This entails investing in robust, intuitively designed and user-friendly digital environments that actively support rich interaction, foster collaborative activities and facilitate effective and timely feedback mechanisms (Shi et al., 2023). These platforms are supplementary tools and the central infrastructure through which BL can deliver flexible access and promote the deep, engaged learning essential for mathematical proficiency.

Furthermore, providing comprehensive technological support necessitates ensuring a seamless and supportive learning experience. This means providing readily available and expert technical assistance to students and lecturers, designed to address technological challenges promptly. By proactively mitigating potential technical frustrations, institutions can ensure that all users can optimally leverage the BL methodology without hindrance. Crucially, a pivotal implication lies in investing in targeted professional development for lecturers. This requires dedicated, ongoing training programs that focus on practical pedagogical approaches for seamlessly integrating the BL strategy (Dwi Lestari & Riatun, 2024). Such training should cover best practices for combining face-to-face and online components, fostering vibrant online discussions, designing authentic assessments within blended learning environments and utilising innovative digital tools to enhance mathematical understanding and application (Cai et al., 2020; Källberg & Roos, 2025). Such comprehensive training is not just about adopting technology; it is about cultivating a more dynamic, relevant and responsive learning environment that genuinely meets the evolving needs of students and comprehensively promotes their holistic intellectual and practical development. By strategically implementing these multifaceted recommendations, higher education institutions in Indonesia can effectively harness the full transformative potential of BL, thereby significantly improving mathematical literacy, fostering crucial skills and ultimately elevating overall student learning satisfaction.

Conclusion

This study set out to analyse the impact of Blended Learning (BL) on students' Learning Satisfaction (LS) in mathematics, specifically examining the mediating roles of Knowledge (KN) and Skill (SK). Our findings reveal that BL has a significant influence on students' knowledge and Skills. Specifically, BL enables students to access learning materials more flexibly and engage with them more deeply, which

demonstrably contributes to an enhanced understanding of mathematical concepts. This improved knowledge then directly impacts students' Skills in solving mathematical problems. Furthermore, the enhanced Skill acquired by students directly increases their Learning Satisfaction, as students feel more confident and capable when confronting academic challenges. These results underscore a robust chain effect: BL positively fosters Knowledge, which enhances Skill, ultimately leading to greater Learning Satisfaction.

These findings carry important implications for educational institutions, particularly within the context of mathematics teaching in Indonesian higher education. Since BL has proven effective in improving student learning outcomes, its application should be expanded and further integrated into higher education curricula. For effective policymaking, institutions should prioritise providing more interactive digital content, robust online learning platforms and comprehensive technological support to ensure students can optimally leverage the BL method. Furthermore, investing in targeted training for lecturers to integrate BL more effectively is crucial. This will help cultivate a more dynamic and relevant learning environment that meets student needs and promotes holistic development.

Despite these significant contributions, this study is subject to several limitations that warrant consideration for future research. First, the reliance on snowball sampling may have limited the generalizability of our findings, as the resulting sample may not be fully representative of the diverse student population across Indonesia. Second, adopting a cross-sectional design restricts our ability to capture dynamic changes in student behaviour or identify the long-term effects of BL on learning satisfaction over time.

For future research endeavours, we recommend employing a longitudinal design to better track changes in student attitudes and behaviours within a BL context, as well as using extended representative sampling techniques to enhance the generalizability of findings. Further avenues for exploration could include investigating other influential variables, such as self-regulation, technology acceptance or learning engagement, as potential factors that contribute to the success of BL in fostering student learning satisfaction.

Disclosure statement

Q4 No potential conflict of interest was reported by the authors.

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The impact of blended learning on knowledge, skills and satisfaction in mathematics: a study in Indonesian universities

Khoerul Umam , Mohd Isha Awang , Bunyamin, Ervin Azhar  & Ishaq Nuriadin

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Abstract

Blended learning, a method that combines face-to-face and online instruction, has had a significant impact on higher education due to the rapid advancement of information and communication technology. This study analysed the effect of blended learning on students' knowledge, skills and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Squares (SEM-PLS) method, the analysis revealed that blended

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[Introduction](#)

[Theoretical framework](#)

[Research methodology](#)

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The impact of blended learning on knowledge, skills and satisfaction in mathematics: a study in Indonesian universities

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ABSTRACT

Blended learning, a method that combines face-to-face and online instruction, has had a significant impact on higher education due to the rapid advancement of information and communication technology. This study analysed the effect of blended learning on students' knowledge, skills and learning satisfaction in mathematics. This study focuses on mathematics learning specifically at the university level. A survey was conducted on 304 Indonesian university students engaged in blended learning for mathematics. Using the Structural Equation Model - Partial Least Squares (SEM-PLS) method, the analysis revealed that blended learning significantly improves students' knowledge and skills, which in turn positively impacts their learning satisfaction. These results were statistically significant. This study offers valuable insights for optimising curriculum design in higher education to enhance the implementation of blended learning and improve the quality of mathematics learning, particularly by highlighting effective teaching methods within this modality.

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Introduction

The rapid evolution of information and communication technology (ICT) has profoundly reshaped operational paradigms across various institutions, with higher education undergoing a significant transformation (Abdi et al., 2025). Global data indicate a widespread adoption of technology, impacting multiple sectors, including education (Tamphu et al., 2024). This pervasive integration facilitates a learning ecosystem that transcends traditional boundaries of time and location. In higher education, technology has become integral to the learning process, empowering students to access course materials and engage in discussions with both instructors and peers online, thereby diminishing their reliance on the physical classroom as the sole learning environment (Alshurideh et al., 2023). This paradigm shift underscores technology's pivotal role in fostering a more dynamic and adaptive learning culture.

The surge in online learning was notably accelerated by the COVID-19 pandemic, which necessitated the closure of educational institutions worldwide and the abrupt shift to remote instruction (Gal & Geiger, 2022; Metaferia et al., 2023). While the pandemic subsided in 2021, enabling the resumption of face-to-face learning, including in Indonesia (Park et al., 2023), the integration of online learning systems within universities has persisted. Students often prefer online learning due to its perceived time-saving benefits and enhanced personal focus (Dolenc & Brumen, 2024). This enduring preference has fostered a new educational culture in Indonesia, characterised by a combination of face-to-face and online learning, commonly known as blended learning (BL) (Dwi Lestari & Riatun, 2024; Hill & Smith, 2023).

BL, a hybrid system that integrates face-to-face and online or distance learning, offers flexibility that aligns with student needs, enabling more effective time management and a more conducive study

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environment (Al-Mekhlafi et al., 2025). In Indonesia, several universities have significantly adopted BL environments, with some reaching up to 80% implementation (Prahmana et al., 2021). However, a recognised challenge within BL, particularly in mathematics instruction, lies in the subject's inherent 'higher level of complexity' (Alonso et al., 2025). Students frequently encounter difficulties comprehending digitally delivered mathematics content (Cho & Kim, 2020). The successful implementation of BL hinges on universities' ability to integrate it with their academic policies seamlessly (Buhl-Wiggers et al., 2023). When universities meticulously design curricula to integrate mathematics learning within a blended framework, it can significantly enhance student learning satisfaction and foster the development of both academic and non-academic skills.

Conversely, Hill and Smith (2023) emphasised that the success of a BL system is contingent upon the students' foundational knowledge. Students' ability to effectively integrate the mathematics learning system with BL methods within their academic environment is directly related to their existing knowledge (Awajan et al., 2024). This encompasses their technological proficiency, as students lacking adequate digital skills may face barriers in accessing materials, which can diminish their overall satisfaction with the mathematics learning process (Mullen et al., 2025).

Prior research has investigated the impact of BL on student satisfaction across diverse geographical contexts, including Australia with McCarthy et al. (2025), China with Wu (2024) and Ghana with Bervell and Umar (2020). These studies consistently reported a significant positive influence of BL on student learning satisfaction in these regions. Studies on BL in mathematics have shown that it can improve mathematical thinking skills, foster positive perceptions, enhance learning outcomes and increase self-regulation and problem-solving abilities (Ali, 2024; Awajan et al., 2024; Hill & Smith, 2023; Kyei-Akuoko et al., 2025; Mullen et al., 2025; Sanusi, 2022).

Specifically, within the Indonesian context, research about BL has predominantly focused on factors such as character, attitude, environment, social factors and usage intentions (Dwi Lestari & Riatun, 2024; Prahmana et al., 2021). Furthermore, as noted by Mullen et al. (2025), the efficacy of BL in mathematics instruction remains a subject of considerable debate. Therefore, a significant research gap exists regarding the specific impact of BL on student satisfaction in mathematics learning within Indonesia, particularly concerning the mediating roles of knowledge and skills. This study aims to address a critical gap by exploring factors that influence student satisfaction in the mathematics learning system in Indonesia, particularly given the limited research on these specific factors in recent years. The Indonesian context is particularly pertinent due to its vast and diverse higher education landscape, ongoing digital transformation initiatives and unique cultural approaches to education, which may influence the dynamics of BL adoption and its outcomes. Indonesia's commitment to improving its PISA scores in mathematics, which have historically been low (Gildore et al., 2025). Makes understanding practical pedagogical approaches, such as BL, particularly crucial in this context.

Building upon the assertions of Prifti (2022) and Al-Mekhlafi et al. (2025), which highlight the dependence of BL success on students' knowledge and expertise, this research posits knowledge and skills as mediating factors. The study aims to investigate whether robust knowledge and relevant skills influence Indonesian students' satisfaction with mathematics learning when adopting the BL method. This research is anticipated to serve as a vital reference for educational institutions, enabling them to comprehend the factors influencing student satisfaction in blended mathematics learning. Such insights will facilitate the adjustment of learning methods to better align with student needs and foster a more active academic environment that embraces technology in teaching and learning, especially in mathematics.

Theoretical framework

Blended learning

According to Alonso et al. (2025), BL is an educational system that effectively combines structured face-to-face instruction with flexible, independent online learning, leveraging digital technology. This system offers significant convenience in terms of time, place and learning methods, allowing students to access materials more flexibly (Uz & Uzun, 2018). The flexibility is particularly beneficial for university students,

who often manage demanding schedules that encompass both academic and extracurricular commitments. Buhl-Wiggers et al. (2023) noted that BL empowers students with direct instruction from lecturers in class and access to rich digital resources such as videos, interactive modules and online discussion forums, which are highly valuable even in mathematics learning. Students who are comfortable with technology and adept at independent learning tend to report higher satisfaction due to their ability to control their independent learning trend to report higher satisfaction due to their ability to control their learning pace (Tubagus et al., 2020). However, this system also inherently demands a higher level of students' discipline and responsibility (Xu et al., 2023). When coupled with adequate institutional support and a well-designed curriculum, implementing BL can significantly enhance the quality of the learning experience and foster greater student satisfaction (Sukkamart et al., 2025; Višňovská & Cortina, 2025).

The impact of BL on student learning satisfaction has been consistently noted. As mentioned, students' comfort with technology and capacity for independent learning often correlate with increased satisfaction, given their enhanced control over their learning rhythm (Rasheed et al., 2020). Furthermore, students' foundational knowledge of basic concepts critically influences the effectiveness of their engagement with BL (Li et al., 2022). Lazarevic and Bentz (2021) highlight that students with strong knowledge of the subject matter are better equipped to access, comprehend and apply information presented online and face-to-face. This foundational knowledge also encompasses students' expertise in leveraging technology to ensure success within the BL environment (Rasheed et al., 2020). Essential skills such as digital literacy, managing technological devices and effective communication are crucial. Students proficient in technological skills exhibit greater adaptability to the BL system, overcoming potential challenges and significantly enhancing their overall learning satisfaction (Engelbrecht & Borba, 2024).

Blended learning and knowledge

Knowledge, as defined by Gayed (2025), is the accumulation of information, facts, skills and understanding acquired through individual experience and education. Broadly, knowledge can be categorised into declarative knowledge (of facts and concepts) and procedural knowledge (of how to perform tasks) (Barbieri & Booth, 2020). Knowledge forms the primary foundation for effective learning in education, especially in mathematics. By integrating face-to-face and online methods, BL can influence and enrich students' mathematical knowledge (Liebendörfer et al., 2023). This model provides wider access to diverse digital information sources, including learning videos and discussion forums, thereby supporting the enrichment of students' declarative knowledge (Mullen et al., 2025). Moreover, the inherent flexibility of BL empowers students to manage their study time and location according to their individual needs, fostering independent exploration of the material (Kyei-Akuoko et al., 2025). Through online accessible learning, students engage with core mathematical concepts and participate in practical applications that reinforce their holistic understanding.

Several prior studies corroborate the positive effect of BL on knowledge acquisition. For instance, Liebendörfer et al. (2023) demonstrated that BL effectively improved nursing students' knowledge, facilitating better knowledge acquisition and task completion. Similarly, Al-Mekhlafi et al. (2025) found that BL enhanced the public health knowledge of students in Korea, attributing this to easier access to materials and the ability to review challenging sections outside of class time. Kyei-Akuoko et al. (2025) further supported this, suggesting that BL can increase student knowledge by minimising fatigue and enhancing focus. Based on these consistent findings, it is hypothesised that:

H1: Blended Learning (BL) positively affects student knowledge in mathematics learning in Indonesia.

Blended learning and skill

As defined by Sukkamart et al. (2025), it refers to an individual's ability to perform specific tasks or jobs proficiently and efficiently. Skills can encompass cognitive, technical, social or managerial competencies

developed through continuous learning and experience (Liu & Yushchik, 2024). Within the educational context, student skills pertinent to BL in mathematics include critical thinking, problem-solving, communication and technical proficiency (Al-Mekhlafi et al., 2025). BL uniquely offers students opportunities to apply their mathematical knowledge through online problem-based activities or case studies, thereby strengthening their critical thinking skills (Kyei-Akuoko et al., 2025). Engelbrecht and Borba (2024). Furthermore, it is highlighted that integrating technology in learning facilitates cross-geographic collaboration via online platforms, fostering the development of broader communication and teamwork skills. Thus, beyond offering flexibility, BL cultivates a rich environment for developing essential mathematical skills in students.

Empirical evidence supports the positive impact of BL on skill development. Moradimokhles and Hwang (2022) found that BL significantly improved students' English language skills. Li et al. (2022) similarly reported that BL substantially enhanced the skills of nursing students, attributing this to the flexibility it provides for students to access materials at their own pace and according to their learning style. Chaeruman et al. (2020) also confirmed that BL significantly influenced skills in clinical supervisor training, noting its higher efficiency. Based on these findings, it is hypothesised that:

H2: Blended Learning (BL) positively affects student skills in learning mathematics in Indonesia.

Knowledge and skill

Knowledge is fundamental to students' mathematics learning process, forming the bedrock for developing more complex skills (Espinoza-Vásquez et al., 2025). In an academic setting, knowledge directly influences how students approach problem-solving, make informed decisions and cultivate professional-level skills (Yang et al., 2022). The critical importance of knowledge lies in its transformative ability to shape skills. A solid knowledge base empowers students to grasp mathematical concepts in depth and effectively apply that understanding to practical situations (Quintos et al., 2025). Furthermore, contemporary education emphasises skills beyond mere cognitive knowledge, expecting students to possess strong problem-solving, critical thinking and adaptive skills to navigate the dynamic changes in mathematics learning (Aoki et al., 2025).

Additionally, robust knowledge enables students to access diverse perspectives, enriching their critical and innovative thinking skills. Thus, knowledge is not merely a passive repository but an active resource that drives innovative skills and effective problem-solving. Research consistently demonstrates this relationship. Murillo-Zamorano and Montanero (2018) found that knowledge significantly influences students' skills in using flipped classrooms. Alfian et al. further substantiated this, reporting a significant impact of knowledge on students' listening and reading comprehension skills. (Murillo-Zamorano & Montanero, 2018) also reinforced this by showing that students' knowledge capacity positively affects their oral presentation skills. Given these established links, it is hypothesised that:

H3: Knowledge positively affects students' skills in mathematics learning in Indonesia.

Knowledge and learning satisfaction

Knowledge is the primary foundation that influences how students comprehend mathematical material and apply it in various contexts (Ibrahim & Alhosani, 2020). In mathematics, this knowledge extends beyond mere facts and theories to encompass the critical analysis abilities needed to interpret information (Barbieri & Booth, 2020). The deeper and more critical a student understands a concept, the greater their satisfaction in studying mathematics (Krawitz et al., 2025). In this context, student learning satisfaction refers to the level of pleasure and contentment students derive from their mathematics learning experience (Wong & Chapman, 2023). This satisfaction is intrinsically linked to how the knowledge acquired impacts their learning journey (Akbar et al., 2025). Students with profound mathematical knowledge are better equipped to assimilate new material, leading to higher satisfaction. Conversely, a lack of knowledge can lead to confusion, frustration and decreased motivation, ultimately reducing their

satisfaction with mathematics learning (Haghighat et al., 2023). Therefore, knowledge is crucial in fostering a positive mathematics learning experience and promoting optimal academic achievement for students.

Prior studies consistently affirm that knowledge influences satisfaction. Haghighat et al. (2023) found that knowledge has a positive impact on learning satisfaction among nursing students. Murillo-Zamorano and Montanero (2018) similarly observe that knowledge significantly influenced students' learning satisfaction in the flipped classroom, mainly because students were required to engage with the material before face-to-face sessions, forming a foundational understanding for discussions. Abuhassna et al. (2020) also emphasised that the quality of knowledge directly affects learning satisfaction in both undergraduate and postgraduate students, enabling them to achieve their academic goals more effectively. Based on these findings, it is hypothesised that:

H4: Knowledge positively affects the mathematics learning satisfaction of students in Indonesia.

Skill and learning satisfaction

Skills represent an individual's learned and experienced abilities, enabling them to perform specific tasks effectively (Smith, 2022). In higher education mathematics, students' foundational skills are crucial to their ability to absorb and apply material effectively in practical situations (Zagouras et al., 2022). Students who perceive themselves as possessing adequate skills tend to exhibit greater confidence, which enhances their ability to understand mathematical material deeply and fosters a sense of self-satisfaction (Alonso et al., 2025). For example, Murillo-Zamorano and Montanero (2018) reported that students' expertise in utilising flipped classrooms significantly affected their learning satisfaction. This is because students proficient in independent learning and time management skills are better equipped to effectively leverage the flipped classroom model. Yoo and Cho (2020) further demonstrated that skills can lead to higher learning satisfaction within the flipped classroom system, given its perceived efficiency in terms of time and place, allowing students to tailor their learning style. Based on these preceding findings, it is hypothesised that:

H5: Skill positively affects the mathematics learning satisfaction of students in Indonesia.

Blended learning, knowledge and learning satisfaction

BL, as an instructional method that integrates face-to-face and online components, offers a flexible approach that accommodates diverse student learning styles and fosters deeper knowledge acquisition (Yehia et al., 2022). In supporting mathematics learning, the blended approach enables students to access information independently and flexibly, thereby profoundly increasing their in-depth knowledge. The broader access to materials afforded by BL also facilitates their mathematical exploration of subjects of interest (Okai-Ugbaje et al., 2020). Enhanced knowledge, in turn, strengthens conceptual understanding in applying BL methods and boosts students' confidence in mastering mathematical knowledge due to BL. It is expected to increase their overall learning satisfaction and encourage continuous engagement (Al-Mekhlafi et al., 2025).

Previous research provides empirical support for this mediated relationship. Adi and Fathoni (2020) demonstrated that BL effectively improved nursing students' knowledge. Similarly, Julia et al. (2020) found that BL enhanced the knowledge of public health students in Korea, attributing this to easier material access and the ability to review difficult content outside of class time. Shimizu and Kang (2025) also noted that BL directly influenced learning satisfaction for these students. Furthermore, Roos and Bagger (2024) confirmed that knowledge impacts learning satisfaction in nursing students. Murillo-Zamorano and Montanero (2018) reinforced this by finding that knowledge significantly affected student learning satisfaction in flipped classrooms. Critically, Sojayan and Khlaisang (2018) specifically highlighted that flipped classrooms could influence student learning satisfaction mediated by knowledge. Synthesising these findings, it is hypothesised that:

H6: Blended learning affects student mathematics learning satisfaction in Indonesia, Mediated by Knowledge.

Blended learning and skill and learning satisfaction

Developing expertise and technological skills is often promoted through blended learning (BL (Zagouras et al., 2022). By utilising BL, students are trained to manage assignment deadlines independently, thereby improving essential self-management skills, which are particularly crucial in mathematics learning due to its often higher level of complexity. Studies have shown a positive impact of BL on skills (Chaeruman et al., 2020). Moradimokhles and Hwang (2022) found that BL influenced students' English language skills in clinical supervisor training attributing its effectiveness to higher efficiency.

Additionally, Fisher et al. (2021) demonstrated that BL positively influences student learning satisfaction in Australian universities. This is often because the blended methods allow students to access materials at any time, facilitating an adjustment of the learning process to their individual needs. Crucially, skill plays a vital role in supporting learning satisfaction. Murillo-Zamorano and Montanero (2018) explained that students' expertise in flipped classrooms can significantly influence their learning satisfaction, as skilled students are better prepared to utilise this learning model effectively. Maarif et al. (2022) also showed that skills lead to higher learning satisfaction in the flipped classroom system. Integrating these insights, it is hypothesised that:

H7: Blended Learning (BL) affects students' mathematics learning satisfaction in Indonesia, mediated by skill.

Blended learning and knowledge and skills

By combining face-to-face instruction with online learning elements, **BL** offers inherent flexibility that enhances student knowledge and facilitates learner interaction (Tubagus et al., 2020). In mathematics, **BL** enables students to learn fundamental concepts independently through digital resources while utilising face-to-face sessions to deepen their understanding of more complex topics (Mullen et al., 2025). The knowledge acquired through such independent learning not only aids students in grasping theoretical concepts but also cultivates vital analytical and problem-solving skills essential for mathematics learning. Empirical evidence supports this link: Wawro and Serbin (2025) showed that **BL** effectively improved nursing students' knowledge. Alonso et al. (2025) also highlighted that **BL** provided easier access to materials, enabling students to repeatedly review difficult sections outside of class to deepen their understanding.

Furthermore, research indicates a direct link between **BL** and skills and knowledge. Roos and Bagger (2024) stated that **BL** influenced students' skills in nursing education, attributing this to the flexibility that allows self-paced learning combined with direct lecturer supervision for practical skill perfection. More specifically, Altas and Mede (2020) found that knowledge significantly influenced students' skills in using flipped classrooms. Hankeln and Prediger (2025) also clarified that knowledge impacts students' listening and reading skills. Given these sequential relationships, it is hypothesised that:

H8: Blended Learning affects students' mathematics learning skills in Indonesia through the mediation of knowledge.

Knowledge, skill and learning satisfaction

Knowledge is the cornerstone of the learning process, particularly in complex disciplines such as mathematics (Gildore et al., 2025). It enables students to comprehend theory and effectively utilise their skills in solving more challenging mathematical problems (Manson & Ayres, 2021). Strong knowledge is, therefore, expected to enhance students' skills, which, in turn, will significantly contribute to their learning satisfaction. Students with robust knowledge tend to develop more effective skills, which directly

enhance their process (Strohmaier et al., 2020). Consequently, the synergistic presence of knowledge and skills is anticipated to facilitate a more meaningful mathematics learning experience, leading to higher levels of student satisfaction (Gurmu et al., 2024).

Various studies support this mediated relationship. Pongsakdi et al. (2020) demonstrated a significant influence of knowledge on students' listening and reading comprehension skills. Geiger et al. (2023) similarly showed that students' knowledge capacity positively affected their oral presentation skills, as good knowledge often correlates with increased confidence in conveying information and structuring ideas.

Furthermore, Zhang et al. (2021) found that knowledge influenced learning satisfaction in nursing students, emphasising its critical role in creating an optimal mathematics learning experience for academic achievement. On the other hand, Murillo-Zamorano and Montanero (2018) the study explained that students' expertise in the flipped classroom significantly influenced their learning satisfaction, as skilled students are better prepared for face-to-face sessions due to their foundational independent learning. Shlomo and Rosenberg-Kima (2025) also reinforced that skills lead to higher learning satisfaction in the flipped classroom system. Based on these cumulative findings, it is hypothesised that:

H9: Knowledge influences the learning satisfaction of mathematics students in Indonesia through Skill mediation.

Research methodology

This study employed a quantitative survey methodology to collect data. The survey was conducted online to gather information from university students across Indonesia who had prior experience with blended learning (BL) in mathematics. A *snowball sampling* method was utilised to recruit participants. This approach involved initially recruiting respondents through social networks, who then referred to other relevant individuals from their contacts. This technique was chosen due to its practicality in accessing specialised and geographically dispersed populations of students engaged in blended mathematics learning. However, it is crucial to acknowledge that the effectiveness and efficiency of snowball sampling are largely contingent on the personal and professional networks of the researcher (Iska et al., 2023). Furthermore, the reliance on self-referral in snowball sampling reduces the sample's representativeness of the findings to the broader student population in Indonesia. This lack of control over the sampling process means the sample may exhibit a degree of homogeneity, potentially overlooking diverse perspectives outside the initially engaged networks (Siri et al., 2020).

The questionnaire was structured into several distinct sections. It began with demographic inquiries, such as age, gender and education level, and subsequently posed questions about respondents' experience with the BL method for mathematics. The online format of the survey ensured broad reach and convenient access for participants. A total of 304 students' responses were collected and deemed eligible for analysis, encompassing diverse demographics regarding gender, education level and gadget usage across various islands in Indonesia (See Table 1 for detailed sample characteristics).

The core variables measured in this study included Blended Learning (BL), Knowledge (KN), Skill (SK) and Learning Satisfaction (LS). Each variable was assessed using a 5-point Likert scale, ranging from 1 ('strongly disagree') to 5 ('strongly agree'), to gauge respondents' perceptions across the various dimensions investigated. This 5-point scale was specifically chosen for its widespread use and familiarity in educational research, which enhances comparability. Its balanced structure provides sufficient nuance without overwhelming respondents (Riyadh et al., 2019). While acknowledging the ordinal nature of Likert scale data, it is a common practice in PLS-SEM to treat such data as suitable for path analysis, given its non-parametric algorithm and robustness (Hair et al., 2023). A detailed description of each variable and its measurement is provided below:

- **Blended Learning (BL):** This construct measures the perceived effectiveness of BL in the educational context, encompassing aspects such as time flexibility, ease of material access and the seamless integration of online and face-to-face learning components. The measurement items for BL were adapted from established instruments by Birbal et al. (2018) and Yehia et al. (2022).

Table 1. Demographic respondents.

Variable	Demographic	Total	Percentage
Gender	Male	142	46.71
	Female	162	53.29
Island	Sumatera	45	14.80
	Java	142	46.71
	Kalimantan	76	25.00
	Sulawesi	41	13.49
Level of education	Undergraduate Degree	221	72.70
	Postgraduate Degree	52	17.11
	Doctoral Degree	31	10.20
Gadgets most often used for studying	Smartphone	129	42.43
	Tablet	21	6.91
	Computer	33	10.86
	Laptop	121	39.80

- **Knowledge (KN):** This variable assessed students' depth of understanding regarding mathematical concepts delivered through BL. The questions aimed to evaluate conceptual clarity, comprehension of presented material and the ability to apply theoretical knowledge effectively. KN measurement items were adapted from previous studies, notably (Murillo-Zamorano & Montanero, 2018).
- **Skill (SK):** This construct focuses on students' proficiency in solving mathematical problems and their adeptness in utilising the tools and resources available on the BL platform. Relevant items included analytical skills, problem-solving capabilities and applying acquired knowledge in practical situations. Murillo-Zamorano and Montanero (2018) adapted SK measurement items from prior research.
- **Learning Satisfaction (LS):** This variable measures a student's overall satisfaction with their learning experience. It specifically included items evaluating satisfaction with the BL methodology, the teaching efficacy of lecturers and the perceived growth in their knowledge and skills. The LS measurement items were adapted from previous studies by Huang (2021) and Sun et al. (2008).

Data analysis was performed using the Structural Equation Model - Partial Least Squares (SEM-PLS) method. This approach was chosen for its suitability in handling complex research models with multiple independent, mediating and dependent variables, its strong emphasis on predictive power by maximising variance explained in endogenous constructs, and its fewer assumptions regarding data distribution, which is beneficial for data collected via Likert scales (Hair et al., 2023; Henseler et al., 2016). The analysis proceeded in two principal stages, adhering to the recommendations put forth by Hair et al. (2023), Henseler et al. (2016) and Rigdon et al. (2017).

The initial stage involved the Evaluation of the Measurement Model, which was crucial for establishing the reliability and construct validity of research variables: Blended Learning, Knowledge, Skill and Learning Satisfaction. This phase ensured that each construct was consistently and accurately measured. Specifically, reliability was assessed through internal consistency using Cronbach's Alpha (α) and Composite Reliability (CR). Validity was established by examining convergent validity (using Average Variance Extracted [AVE] values and indicator outer loadings) and discriminant validity (using the Heterotrait-Monotrait Ratio [HTMT] criterion). Additionally, content validity was ensured through expert review of the questionnaire items to confirm their relevance and comprehensiveness (as noted in the instrument description).

Following the successful validation of the measurement model, the subsequent stage involved evaluating the Structural Model. This phase focused on testing the hypothesised relationships between the identified latent variables. Path analysis examined both direct and indirect effects among these variables. To robustly assess the significance of these direct and indirect paths, a bootstrap resampling technique with 5,000 samples was employed. This approach yields a more robust estimation of standard errors, thereby providing a more precise determination of the statistical significance of the effects observed between variables.

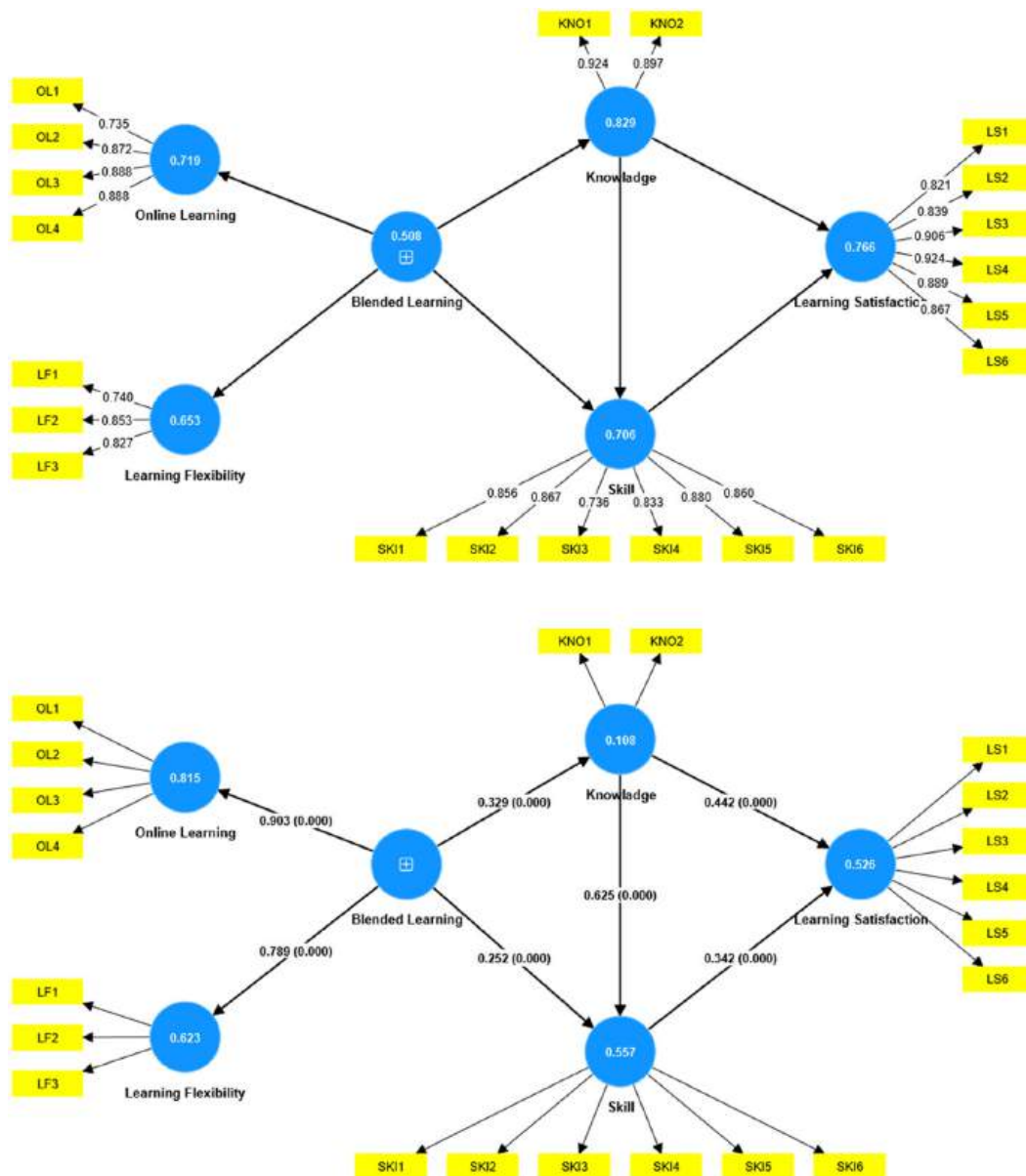


Figure 1. Outer and inner model.

Results and discussions

This section presents the findings derived from the statistical analysis, specifically focusing on the evaluation of the measurement model and the structural model. We detail the outcomes of our investigation into the hypothesized relationships between the identified latent variables, followed by a comprehensive discussion that interprets these results in the context of existing literature and their implication for mathematics education (Figure 1).

Evaluation measurement model

Before proceeding with hypothesis testing, a rigorous evaluation of the measurement model was conducted to establish the reliability and validity of all constructs. This critical step encompassed assessments of indicator reliability, internal consistency reliability, convergent validity and discriminant validity, adhering to the established guidelines outlined by Hair et al. (2023).

Indicator reliability

Indicator reliability was initially assessed by examining the outer loading (OL) values. These values quantify the extent to which the variance of each indicator is explained by its underlying construct, thereby reflecting the reliability of the indicator. The widely accepted recommendation for outer loading values is greater than 0.70. As presented in Table 2, all outer loading values in this study surpassed this threshold, confirming that the indicator reliability for all constructs has been robustly met.

Internal consistency reliability

Cronbach's Alpha (α) and Composite Reliability (CR) were evaluated to ascertain the internal consistency reliability. These metrics are crucial for determining the degree to which indicators designed to measure the same latent construct are intercorrelated and consistent. As shown in Table 2, both the Cronbach's Alpha and Composite Reliability values for all constructs exceeded 0.70. This outcome indicates that the indicators employed in this study are internally consistent and can, therefore, be considered as reliable, fully aligning with the recommendations provided by Hair et al. (2023).

Convergent validity

Convergent validity was assessed through the Average Variance Extracted (AVE). The AVE value indicates the variance a construct explains in its indicators relative to the amount of variance due to measurement error. A high AVE value signifies that all items within a construct converge well, collectively explaining a substantial portion of their shared variance. Manley et al. (2021) recommend an AVE value of 0.50 or higher. As evidenced in Table 2, all AVE values in this study were greater than 0.50, thus confirming the convergent validity of all constructs.

Discriminant validity

Discriminant Validity was examined to ensure that each construct is empirically distinct and sufficiently differentiated from other constructs within the structural model. Henseler et al. (2015) recommend utilizing the Heterotrait-Monotrait (HTMT) for a more robust discriminant validity assessment, with a recommended threshold value below 0.90. Based on the results presented in Table 3, all HTMT values were

Table 2. Outer loading and convergent validity.

Variable	Item	OL	α	CR	AVE
Knowledge	KNO 1	0.924	0.795	0.907	0.829
	KNO 2	0.897			
Blended learning	Online learning	0.789	0.834	0.877	0.508
	Learning flexibility	0.903			
Learning flexibility	LF 1	0.740			
	LF 2	0.853			
	LF 3	0.827			
Online learning	OL 1	0.735			
	OL 2	0.872			
	OL 3	0.888			
	OL 4	0.888			
Learning satisfaction	LS 1	0.821	0.938	0.951	0.766
	LS 2	0.839			
	LS 3	0.906			
	LS 4	0.924			
	LS 5	0.889			
	LS 6	0.867			
Skill	SKI 1	0.856	0.916	0.935	0.706
	SKI 2	0.867			
	SKI 3	0.736			
	SKI 4	0.833			
	SKI 5	0.880			
	SKI 6	0.860			

Notes: OL = Outer Loading, CR = Composite Reliability, AVE = Average Variance Extracted.

Table 3. Discriminant validity

	Blended learning	Knowledge	Learning satisfaction	Skill
Blended learning				
Knowledge	0.400			
Learning satisfaction	0.477	0.785		
Skill	0.526	0.827	0.705	

Table 4. Path coefficients, effect size and collinearity test.

	β	T-stats	P-values	VIF	f2
BL -> KNO	0.329	5.529	0.000	1.000	0.122
BL -> SKI	0.252	6.032	0.000	1.122	0.128
KNO -> LS	0.442	7.186	0.000	2.003	0.206
KNO -> SKI	0.625	14.792	0.000	1.122	0.786
SKI -> LS	0.342	4.985	0.000	2.003	0.123
BL -> KNO -> LS	0.145	4.272	0.000	–	–
BL -> KNO -> SKI	0.206	5.290	0.000	–	–
BL -> SKI -> LS	0.086	3.669	0.000	–	–
KNO -> SKI -> LS	0.214	4.777	0.000	–	–

below 0.90. This outcome unequivocally indicates that discriminant validity has been established for all constructs, rendering them suitable for subsequent analysis within the structural model.

Evaluation of the structural model

Hypothesis testing was conducted by analysing the path coefficients and their statistical significance. This was achieved through a robust bootstrapping procedure involving 5000 resamples with a 95% bootstrap confidence level, as Henseler et al. (2016) recommended. The results for each hypothesised path are presented in detail below and are summarised comprehensively in Table 4.

H1: Blended Learning (->) knowledge ($\beta = 0.329$, T-stat 5.529, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Knowledge (KN)** is **positive and significant**, thus providing strong support for **H1**. This finding robustly indicates that the strategic implementation of BL notably enhances students' knowledge acquisition. This result is consistent with the extant literature, particularly Al-Mekhlafi et al. (2025), which posits that BL facilitates easier access for students to revisit challenging material, thereby deepening their comprehension of complex mathematical concepts. The inherent flexibility of BL, which allows students to learn at their own pace, is profoundly important in mathematics. This subject often demands extensive time and repeated exposure to grasp abstract concepts.

Furthermore, the expensive access to diverse digital resources, such as interactive modules and video tutorials, empowers students to explore various cognitive pathways to internalise complex mathematical ideas. Liebendörfer et al. (2023) underscored that the BL methodology can significantly augment student engagement and motivation, particularly for demanding subjects like mathematics, owing to its adaptable learning styles. This finding aligns with research indicating that knowledge acquired through BL transcends mere theoretical understanding, encompassing the ability to apply concepts in broader contexts.

H2: Blended Learning (->) skill ($\beta = 0.252$, T-stat = 6.032, $p < 0.001$). The direct effect of **Blended Learning (BL)** on **Skill (SK)** is also **positive and significant**, confirming the acceptance of **H2**. This underscores that BL effectively contributes to the development of students' mathematical skills. Sukkamart et al. (2025) emphasise the critical role of skills in technology-enhanced learning environments, where BL uniquely enables students to hone the technical and analytical proficiencies indispensable for solving complex mathematical problems. The strategic integration of technology within the learning process, including online discussion forums and computer-based practice exercises, provides invaluable opportunities for students to practice and apply their mathematical knowledge in practical situations actively. This finding resonates strongly with Dwi Lestari and Riatun (2024), who demonstrated that BL substantially increases students' skills by fostering independent learning and the flexible application of relevant abilities across diverse scenarios. In mathematics, BL is instrumental in helping students practice problem-solving as frequently as needed to solidify their understanding.

H3: Knowledge (->) Skill ($\beta = 0.625$, T-stat = 14.792, $p < 0.001$) The path from **Knowledge (KN)** to **Skill (SK)** exhibits a powerful positive and significant, profoundly indicating that higher levels of knowledge lead to significant improvements in with the pedagogical principle that a solid and deep knowledge base forms the essential foundation for cultivating higher-order skills, particularly in complex subjects such as mathematics. In mathematics education, an in-depth understanding of theoretical concepts provides students with a robust framework to apply their comprehension in practical contexts, including rigorous problem-solving and comprehensive analysis. According to Sanusi (2022), the knowledge acquired through blended learning, it empowers students to enhance their problem-solving capabilities by providing access to diverse digital resources that facilitate a deeper conceptual understanding. With a firm theoretical grasp, students are better prepared to apply their knowledge in real-world scenarios, which, in turn, sharpens their critical and analytical thinking skills. Moreover, Xu et al. (2023) highlighted that declarative knowledge (factual and conceptual understanding) frequently serves as the indispensable precursor for the development of procedural skills (the 'how-to' aspect of problem-solving), both of which are paramount in mathematics learning. Students with strong declarative knowledge are better equipped to develop procedural skills, such as solving complex equations or intricate problems, which facilitates the emergence of more sophisticated skills, including critical thinking and advanced problem-solving abilities. Within the BL context, students can strategically utilise various online materials to reinforce their foundational knowledge, subsequently applying that knowledge in practice questions or collaborative disciplines that demand high-level problem-solving skills.

H4: Knowledge (->) Learning Satisfaction ($\beta = 0.442$, T-stat = 7.186, $p < 0.001$) The relationship between **Knowledge (KN)** and **Learning Satisfaction (LS)** demonstrates strong **positive and significant effect**, suggesting that students who possess greater knowledge exhibit higher satisfaction with their learning experience. This supports **H4**. The acquisition of knowledge during the learning process has a significant and direct impact on learning satisfaction. This suggests that *students with sufficient knowledge are generally more satisfied* with their learning experience. This finding is entirely consistent with research Alrajhi (2024), which indicates that increased knowledge during the learning process contributes to elevated learning satisfaction, particularly when students feel empowered to apply their acquired knowledge in a practical context. In mathematics education, learning satisfaction is frequently correlated with how thoroughly students grasp the concepts taught and their demonstrable ability to solve related problems. When students perceive that they gain a deep understanding of mathematical topics through BL, their satisfaction with the learning process markedly increases as they feel more prepared and confident in navigating academic challenges.

H5: Skill (->) Learning Satisfaction ($\beta = 0.342$, T-stat = 4.985, $p < 0.001$). The effect of **Skill (SK)** on **Learning Satisfaction (LS)** is also **significant and positive**, implying that students who acquire better skills tend to be more satisfied with their learning outcomes. Thus, **H5 is supported**. This study found that the skills students acquired during their learning journey significantly contributed to their overall learning satisfaction. Brandsæter and Berge (2025) articulated that students with superior skills in utilising learning technology typically report higher satisfaction with their learning process, primarily because they feel more capable of solving problems and effectively managing their independent learning. In the domain of mathematics education, skills cultivated through BL, such as analytical thinking and problem-solving capabilities, instil greater self-confidence in students, which ultimately translates into increased satisfaction. Students who perceive they have developed competencies relevant to mathematics learning, such as critical and analytical thinking skills, tend to be more satisfied because they can discern the practical applications of their newly acquired knowledge. This finding is further reinforced by Fan et al. (2022), which states that skills developed through technology-based learning substantially increase student satisfaction, as these skills better equip them to confront challenges in real-world challenges.

Indirect effects (mediation analysis)

The study also thoroughly investigated the *indirect effects* to ascertain the crucial mediating roles of *Knowledge* and *Skill* within the hypothesised relationships.

H6: Blended Learning (->) Knowledge (->) Learning Satisfaction ($\beta = 0.145$, T-stat = 4.272, $p < 0.001$) The indirect effects of BL on Learning Satisfaction **through Knowledge** are **significant**,

providing clear support for **H6**. This mediation effect profoundly highlights the *important role of knowledge acquisition* in bridging the relationship between BL and students' learning satisfaction, especially in the context of mathematics. BL, with its integrated approach that combines online and face-to-face instruction, provides students with enhanced overall learning satisfaction.

H7: Blended Learning (->) Skill (->) Learning Satisfaction ($\beta = 0.086$, $T\text{-stat} = 3.669$, $p < 0.001$). The indirect effects of BL on Learning Satisfaction **through Skill** are also **significant**, although with a comparatively smaller effect size. This finding supports **H7**. This suggests that BL indirectly contributes to learning satisfaction by fostering the development of essential skills. As observed in this study, the acquisition of enhanced skills confers higher self-confidence on students, which, in turn, significantly enhances their satisfaction with the learning experience. Cevikbas and Kaiser (2023) demonstrated that students who feel proficient in utilising learning technology and are adept at applying mathematical concepts tend to be more satisfied with their learning process. In mathematics education, skills cultivated through BL, such as the ability to solve complex problems or fully utilise mathematical technology (e.g. graphing calculators, modelling software), play a pivotal role in increasing students' self-confidence. The more skilled students become in leveraging these tools, the more satisfied they are with their learning outcomes (Engelbrecht & Borba, 2024). This indirect effect illustrates that BL not only confers direct benefits in skill enhancement but also contributes to increased student learning satisfaction through the holistic development of these crucial skills.

H8: Blended Learning (->) Knowledge (->) Skill ($\beta = 0.206$, $T\text{-stat} = 5.290$, $p < 0.001$) The indirect effects of BL **through Knowledge** are **significant**, profoundly indicating that **knowledge** acts as a crucial mediator between BL experiences and subsequent skill development. This provides robust support for **H8**. Knowledge indeed serves as a potent mediator in the relationship between BL and skills. As highlighted in the seminal study by Sukkamart et al. (2025), a robust theoretical knowledge base often forms an indispensable foundation for the development of practical skills. In the context of mathematical education, students who possess a deep and nuanced understanding of mathematical theories are inherently better at applying this intricate knowledge in solving real-world problems, which demonstrably improves their skills. BL uniquely provides students with the opportunity to learn mathematics in diverse formats (such as comprehensive texts, engaging videos and interactive exercises), allowing them to learn in a manner that optimally suits their learning styles. The profound knowledge gained through this dynamic method then empowers students to develop superior skills in solving mathematical problems, both within the structured confines of the classroom and in broader, real-life contexts. Tran and O'Connor (2024) found that knowledge acquired through online learning contributed significantly to the development of practical skills in domains requiring deep conceptual understanding, including mathematics.

H9: Knowledge (->) Skill (->) Learning Satisfaction ($\beta = 0.214$, $T\text{-stat} = 4.777$, $p < 0.001$) The final mediation effect of knowledge on learning Satisfaction **through Skill** is **significant**, unequivocally indicating that **skills** act as a critical mediator between knowledge acquisition and learning satisfaction. This leads to the acceptance of **H9**. Students who cultivate a deep understanding of mathematical concepts are considerably more likely to effectively apply their knowledge in practical situations, which directly fosters superior skill development. Demir et al. (2022) found that declarative knowledge (theoretical understanding) frequently functions as an important foundation for the development of procedural skills (practical application). In mathematics education, strong theories of knowledge empower students to develop more sophisticated analytical and problem-solving skills, ultimately leading to increased learning satisfaction. Within the BL environment, the profound knowledge gained through various online resources enables students to actively practice and strengthen their skills in solving mathematical problems. These enhanced skills contribute to achieving better academic results and significantly increase students' satisfaction with the learning process, as they feel more prepared and competent to overcome academic challenges effectively.

Coefficients of determination (R^2)

The coefficients of determination (R^2) quantify the proportion of variance in the endogenous construct that the exogenous construct within the research model can explain. Hair et al. (2023) provide general guidelines, suggesting that R^2 values of 0.25, 0.50 and 0.75 typically indicate weak, moderate and strong levels of explanatory power, respectively. As presented in Table 5, the Adjusted R^2 values for this study

Table 5. Coefficient of determination.

	R-square	Adjusted R-square
Knowledge	0.108	0.106
Learning Satisfaction	0.526	0.523
Skill	0.557	0.554

demonstrate that the model effectively explains 52.3% of the variation in Learning Satisfaction and 55.4% of the variation in Skill. This suggests that the construct of BL, Knowledge and Skill, as conceptualised in this model, collectively exhibit a moderate to strong explanatory power over student learning satisfaction and skill development in mathematics.

Effect size (f^2)

Effect Size (f^2) is a crucial metric employed in SEM analysis to measure the substantive impact of an exogenous construct on an endogenous construct. This is achieved by calculating the R^2 value after systematically removing one exogenous construct at a time (Hair et al., 2023). Li et al. (2022) established widely accepted benchmarks, categorising f^2 values of 0.02 as a small effect, 0.15 as a moderate effect, and 0.35 as a significant effect. For example, as detailed in Table 4, the effect of Knowledge on Skill ($f^2 = 0.786$) is substantial, unequivocally indicating a significant and profound contribution of knowledge to skill development. Other relationships, such as Knowledge on Learning Satisfaction ($f^2 = 0.206$), also demonstrate moderate effects, further underscoring the critical importance of knowledge acquisition in shaping positive learning outcomes within an educational context.

Potential causes for variations from related studies

While the findings of this study broadly resonate with the growing body of literature on the benefits of BL, academic rigour demands an acknowledgement that research outcomes can exhibit variations across different studies. Such discrepancies are not uncommon and often stem from a confluence of interconnected factors. One primary contributor to these variations is BL's specific modality and implementation. The precise balance between online and face-to-face components, the specific digital tools and platforms employed, and the underlying pedagogical approaches adopted can differ significantly between studies (Alonso et al., 2025; Engelbrecht & Borba, 2024; Tubagus et al., 2020). For instance, a BL model that is heavily reliant on synchronous online discussions might yield different results than one that emphasises asynchronous interactive modules, leading to distinct impacts on student engagement and learning outcomes.

Furthermore, contextual factors play a profound role in shaping research findings. The cultural and educational landscape in which a study is conducted, including the specific characteristics of the Indonesian higher education system, unique student demographics, pre-existing levels of technological exposure and the prevailing digital infrastructure, can all profoundly influence how students perceive, adapt to and ultimately benefit from BL. These localised variables can create subtle yet significant differences in learning experiences compared to studies conducted in, for example, Western educational settings with different pedagogical traditions or access to technology, highlighting the importance of situated learning perspectives (Kyei-Akuoko et al., 2025). Similarly, discipline-specific nuances are also critical. While this study focused on mathematics, the effectiveness of BL and the precise mediating roles of knowledge and skill may vary across diverse academic disciplines, owing to inherent differences in subject matter complexity, district learning objectives and the unique cognitive skills required for mastery in each field (Liebendörfer et al., 2023).

Finally, variations can also arise from methodological differences, including the operationalisation and measurement of constructs such as 'Knowledge', 'Skill' and 'Learning Satisfaction'. Different measurement instruments or scales can capture distinct facets of these constructs, influencing the observed relationship (Engelbrecht & Borba, 2024). Additionally, the characteristics of the student samples, such as their academic background, intrinsic motivation levels or prior digital literacy, while the sampling methodologies employed the use of non-probability sampling, which, as a limitation of this study, can impact

generalizability, can lead to notable differences in findings when comparing across studies (Meikleham & Hugo, 2020). Acknowledging these potential sources of variation is fundamental for a nuanced interpretation of research findings and for advancing a more sophisticated understanding of BL's complex effectiveness across diverse educational landscapes.

Implications for higher education

The robust findings from this study offer a profound understanding and carry significant, actionable implications for educational institutions, particularly within the dynamic landscape of mathematics teaching in Indonesian higher education. Since BL has been demonstrably proven effective in significantly improving key student learning outcomes, specifically fostering deeper Knowledge acquisition and enhancing essential skills development (as evidenced by the current study's findings, consistent with broader trends noted by Abuhassna et al. (2020)—its strategic application and broader integration within higher education curricula should be a paramount priority for institutions.

Higher education institutions should consider several key focus areas to optimise the utilisation of these valuable research results. Firstly, there is a compelling need to prioritise and invest in developing highly interactive and contextually relevant digital content. This includes designing and providing a rich array of engaging online learning materials, such as sophisticated simulations, adaptive interactive exercises and meticulously produced high-quality video tutorials, all meticulously tailored to address the unique complexities of mathematical concepts (Strohmaier et al., 2020). Such a proactive approach will support diverse learning styles and empower students to achieve self-paced mastery, a critical component of deep learning in mathematics. Secondly, institutions must continue to strengthen and enhance their online learning platforms. This entails investing in robust, intuitively designed and user-friendly digital environments that actively support rich interaction, foster collaborative activities and facilitate effective and timely feedback mechanisms (Shi et al., 2023). These platforms are supplementary tools and the central infrastructure through which BL can deliver flexible access and promote the deep, engaged learning essential for mathematical proficiency.

Furthermore, providing comprehensive technological support necessitates ensuring a seamless and supportive learning experience. This means providing readily available and expert technical assistance to students and lecturers, designed to address technological challenges promptly. By proactively mitigating potential technical frustrations, institutions can ensure that all users can optimally leverage the BL methodology without hindrance. Crucially, a pivotal implication lies in investing in targeted professional development for lecturers. This requires dedicated, ongoing training programs that focus on practical pedagogical approaches for seamlessly integrating the BL strategy (Dwi Lestari & Riatun, 2024). Such training should cover best practices for combining face-to-face and online components, fostering vibrant online discussions, designing authentic assessments within blended learning environments and utilising innovative digital tools to enhance mathematical understanding and application (Cai et al., 2020; Källberg & Roos, 2025). Such comprehensive training is not just about adopting technology; it is about cultivating a more dynamic, relevant and responsive learning environment that genuinely meets the evolving needs of students and comprehensively promotes their holistic intellectual and practical development. By strategically implementing these multifaceted recommendations, higher education institutions in Indonesia can effectively harness the full transformative potential of BL, thereby significantly improving mathematical literacy, fostering crucial skills and ultimately elevating overall student learning satisfaction.

Conclusion

This study set out to analyse the impact of Blended Learning (BL) on students' Learning Satisfaction (LS) in mathematics, specifically examining the mediating roles of Knowledge (KN) and Skill (SK). Our findings reveal that BL has a significant influence on students' knowledge and Skills. Specifically, BL enables students to access learning materials more flexibly and engage with them more deeply, which demonstrably contributes to an enhanced understanding of mathematical concepts. This improved knowledge then directly impacts students' Skills in solving mathematical problems. Furthermore, the enhanced Skill

acquired by students directly increases their Learning Satisfaction, as students feel more confident and capable when confronting academic challenges. These results underscore a robust chain effect: BL positively fosters Knowledge, which enhances Skill, ultimately leading to greater Learning Satisfaction.

These findings carry important implications for educational institutions, particularly within the context of mathematics teaching in Indonesian higher education. Since BL has proven effective in improving student learning outcomes, its application should be expanded and further integrated into higher education curricula. For effective policymaking, institutions should prioritise providing more interactive digital content, robust online learning platforms and comprehensive technological support to ensure students can optimally leverage the BL method. Furthermore, investing in targeted training for lecturers to integrate BL more effectively is crucial. This will help cultivate a more dynamic and relevant learning environment that meets student needs and promotes holistic development.

Despite these significant contributions, this study is subject to several limitations that warrant consideration for future research. First, the reliance on snowball sampling may have limited the generalizability of our findings, as the resulting sample may not be fully representative of the diverse student population across Indonesia. Second, adopting a cross-sectional design restricts our ability to capture dynamic changes in student behaviour or identify the long-term effects of BL on learning satisfaction over time.

For future research endeavours, we recommend employing a longitudinal design to better track changes in student attitudes and behaviours within a BL context, as well as using extended representative sampling techniques to enhance the generalizability of findings. Further avenues for exploration could include investigating other influential variables, such as self-regulation, technology acceptance or learning engagement, as potential factors that contribute to the success of BL in fostering student learning satisfaction.

Disclosure statement

No potential conflict of interest was reported by the authors.

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