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Revealing the dynamics of online mathematics learning in higher education: A students' perspective

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Abstract

The surge in technological advancements has made online learning increasingly significant, especially during the COVID-19 pandemic. However, it presents specific challenges, particularly in abstract disciplines like mathematics at the university level. This study aims to identify the factors that either facilitate or hinder university students' experiences with online mathematics education during the pandemic. Employing a quantitative survey methodology, the research gathered data from 337 mathematics education students in Indonesia through random sampling. Google Forms conducted the survey, which evaluated eight key aspects: learning motivation, participation, course materials, facilities and infrastructure, interaction, technology skills, learning environment, and self-regulated learning. The results reveal that the primary factors supporting online mathematics learning include high student motivation, active participation, adequate technological skills, and strong self-regulation. Conversely, the main barriers are unstable internet connectivity, high data costs, complex course content, limited interaction, and suboptimal learning environments. These findings suggest that mathematics educators can improve online learning by developing interactive and engaging experiences. Strategies to achieve this may include integrating multimedia resources, optimizing task design, facilitating discussion forums, and creating a stimulating learning atmosphere.

Keywords: inhibiting factor, mathematics, online learning, supporting factor

Introduction

The rapid progress in science and technology, especially in the context of Industry 4.0 has had a substantial impact on various aspects of human life, including education. This technological revolution has facilitated a transition from traditional classroom-based education to online learning, enabled by digital technologies. Online learning, which involves leveraging the internet to access educational materials, engage in classroom interactions, and facilitate

knowledge transfer, is not a new concept (Moore et al., 2011). However, its adoption increased dramatically during the COVID-19 pandemic, making it essential for educational continuity. Singh and Thurman (2019) describe online learning as a comprehensive educational approach that uses both synchronous and asynchronous online communication through various internet-connected devices like smartphones and laptops. This shift highlights the flexibility of online learning, allowing it to overcome geographical limitations (Bower et al., 2015) and emerge as a practical alternative during times of crisis (Basilaia & Kvavadze, 2020).

Online learning offers significant advantages in terms of practicality and accessibility, allowing learners to engage with educational content at any time and from any location (Means, 2010; Callaway, 2012; Özyurt et al., 2013; Nakamura et al., 2018). This flexibility is supported by various Learning Management Systems (LMS) like Edmodo, Google Classroom, and Moodle (Varalakshmi & Arunachalam, 2020). Virtual conferencing tools, such as Google Meet and Zoom, further enhance these online learning environments by facilitating interactive sessions, thereby improving student motivation and educational outcomes (Huang et al., 2020). Yohannes et al (2021) highlight that the flexibility of online learning, unrestricted by space or time, presents a multitude of implementation opportunities.

However, despite these benefits, online learning cannot entirely substitute for traditional face-to-face education (Onyema et al., 2020). An effective learning experience relies on active participation, which can be more challenging in online settings due to the absence of direct human interaction (Levy & Goldfarb, 2021; Geary et al., 2019). This difference highlights the need for innovative strategies to maintain student engagement and promote active learning in a virtual environment.

Transitioning to online learning presents several challenges, requiring reliable internet access, appropriate devices, and a commitment to self-directed learning (Baticulon et al., 2021; Fabito et al., 2020). The digital divide exacerbates these issues, particularly in developing countries, where disparities in technology access are more pronounced (Bringula et al., 2021; Salac & Kim, 2016). The COVID-19 pandemic has compelled schools and universities to rapidly adopt online learning, despite many institutions having limited experience with e-learning (Zaharah & Kirilova, 2020). Studies (Arkorful & Abaidoo, 2014; Irfan, 2015) show that while online learning at the university level offers certain advantages, it also comes with notable disadvantages. Beyond issues of internet access, common challenges include a lack of proficiency in information technology, increased risk of plagiarism, low student autonomy in learning, and limited interaction among learners and educators (Özyurt et al., 2013; Nakamura et al., 2018; Himmi et al., 2021; Yohannes et al., 2021).

In Indonesia, Minister of Education and Culture Regulation Number 109 of 2013 addresses distance education at the tertiary level, establishing guidelines for effective distance learning. The rule lists three important things that show how well something is working in this area: (1) how well learning materials, technology-based resources, practical learning media, the use of information and communication technology, and self-evaluation work; (2) how well interaction works in distance learning, including how teachers act, how students interact with teachers, and how long learning sessions last; and (3) how well students understand, including

how well they learn on their own, how motivated they are, and how involved they are in learning. Compliance with this regulation provides a framework for Indonesian educators to guide the implementation of effective online learning practices.

When addressing specific subjects like mathematics, with its reliance on logical reasoning and interconnected concepts, unique challenges arise due to its abstract nature, extensive use of symbols, and specialized terminology. University-level mathematics courses such as abstract algebra, real analysis, and geometry often prove difficult for students given their complex concepts and theorem-heavy content. The adaptation of e-learning platforms for mathematics, as emphasized by Yong and Edwin (2018), is essential for effectively overcoming these challenges. Additionally, distance learning environments make it more challenging for instructors to convey complex mathematical ideas through written words and symbolic language (Cassibba et al., 2020).

Given this context, exploring the supporting and inhibiting factors of online learning is crucial to understanding the dynamics, barriers, and potential of online education in the current digital age. This research aims to uncover these factors, foster the development of more effective learning strategies, and improve education through technological integration. While earlier studies primarily focused on the barriers to online mathematics learning at the school level (Himmi et al., 2021; Almarashdi & Jarrah, 2021; Ariyanti & Santoso, 2020; Mailizar et al., 2020; Moreno et al., 2020; Wijaya, 2021), there has been limited investigation into the challenges faced by university students. Some studies have examined specific universities, such as those evaluating the impact of the pandemic on students at various Malaysian universities (Shahzad et al., 2021) or analyzing mathematics learning in Jakarta universities (Kamsurya, 2020). Others, like Lisnani & Tanujaya (2021), explored perceptions of advanced mathematics learning at Universitas Katolik Musi Charitas.

The present research is distinctive in its focus on the perspectives of mathematics education students from universities across Indonesia, including both public and private institutions. It seeks to provide comprehensive insights into the reality of online mathematics learning at the university level in Indonesia, identifying both the supporting and inhibiting factors from the students' viewpoints. These findings could be instrumental in evaluating and improving the quality of online learning in higher education, particularly in developing countries. This research aims to contribute to the development of more effective teaching strategies and support systems that enhance the online learning experience by delving into these perspectives.

Methods

The research employed a quantitative descriptive approach with a survey method to understand the dynamics of online mathematics learning from the perspective of college students. This approach enabled the researchers to describe and analyze phenomena related to online learning experiences, as well as identify both supporting and inhibiting factors during the COVID-19 pandemic. By posing specific questions and compiling their responses, the survey method

collects data from a group of people to examine their characteristics, opinions, attitudes, or experiences (Leedy & Ormrod, 2016).

We used the survey method in this study to get direct feedback from students about their online mathematics learning experiences. Random sampling was necessary because the researchers were unable to control the respondents' identities or university affiliations. The only restriction was that the participants must be students enrolled in mathematics education programs in Indonesia. Factors such as the students' gender, age, and whether they were from public or private universities were not considered.

A questionnaire collected data from students in mathematics education programs across 15 universities, encompassing 12 provinces in Indonesia, yielding 337 responses. The diverse sample provides a broad perspective on the experiences of university-level mathematics education students in a variety of settings. This methodology's application allowed the researchers to uncover significant insights into the factors influencing the success of online mathematics learning during the pandemic.

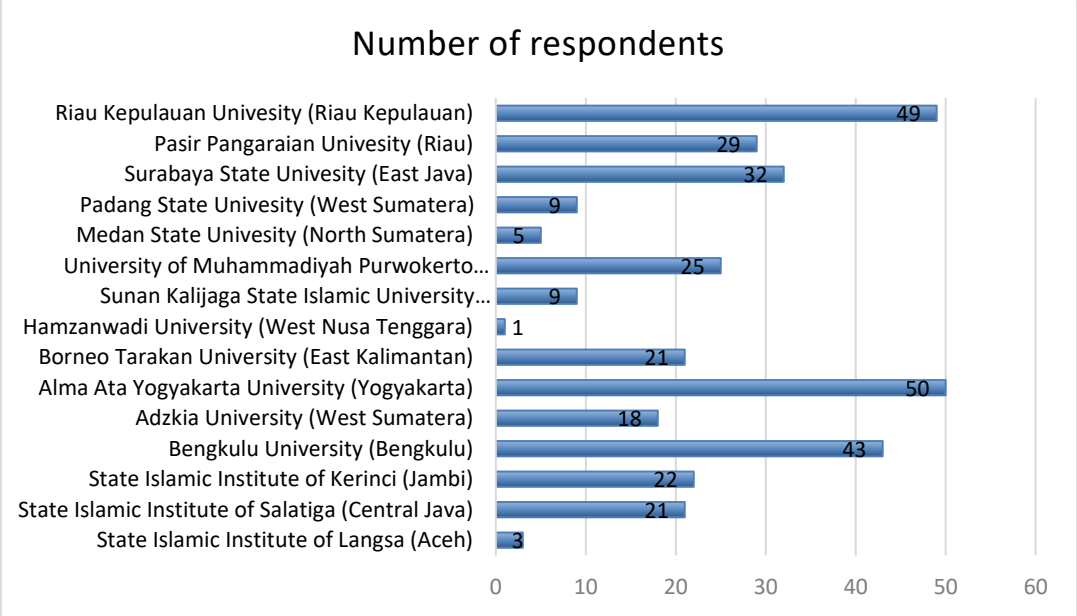

Figure 1. Respondents' university affiliation

The study collected data through a questionnaire, employing an indirect method where researchers did not directly engage with respondents. Expert judgment validated the questionnaire, comprising 31 statements, to ensure its accuracy and relevance. To assess the reliability of the instrument, the researchers used the Intraclass Correlation Coefficient (ICC), which resulted in a correlation index of r_{11} = 0.882, indicating high reliability (Zaki, 2017). This high correlation suggests that the questionnaire consistently measures the aspects it was designed to evaluate.

The questionnaire was distributed online through Google Forms, allowing for easy access and broader distribution to the target population. The questionnaire's use of closed-ended statements allowed for an objective assessment of the various factors influencing online

mathematics learning. The research focused on eight key aspects that could either support or hinder online learning, according to Minister of Education and Culture Regulation Number 109 of 2013, which outlines specific indicators for effective distance learning. These eight aspects, detailed in Table 1, include learning motivation, participation, materials, facilities, infrastructure, interaction, technology skills, learning environment, and self-regulated learning. By examining these factors, the study aimed to provide insights into the underlying dynamics of online mathematics learning in university settings, particularly during the COVID-19 pandemic.

Table 1. Questionnaire guidelines

Aspects	Sum of item	Item number	
		Positive	Negative
Learning motivation during online learning	4	2, 3	1,4
Students' participation in online learning	4	6, 8	5, 7
Lecture materials	4	11, 12	9, 10
Facilities and infrastructure	4	13, 16	14, 15
Students' interaction in online learning	4	17, 19	18, 20
Students' technology skills mastery	3	21, 22	23
Students' learning environment	4	-	24, 25, 26, 27
Students' self-regulated learning	4	28, 29	30, 31

The data analysis for the students' questionnaire responses was conducted using a 4-point Likert scale, with response options of "Strongly Agree," "Agree," "Disagree," and "Strongly Disagree" (William et al., 2016). This modification of the traditional Likert scale, which eliminates a neutral response, aims to capture more accurate data by reducing ambiguity from respondents' indecisiveness or preference for neutrality. By removing the middle option, this adjusted scale helps minimize central tendency effects and encourages respondents to take a clear stance, thereby providing more definitive insights into their attitudes.

We analyzed the data from the questionnaire using a frequency tabulation procedure and calculated the percentage of responses for each item. The analysis of positive statements focused on the percentage of respondents who selected "Strongly Agree" and "Agree," while the analysis of negative statements centered on the percentage of those who chose "Disagree" and "Strongly Disagree" (Enu et al., 2015). This approach allows for an understanding of the distribution of opinions and a clearer identification of trends.

Tables or diagrams displaying the relationships between various data points presented the analysis's results. We interpreted and narratively described these graphical presentations to determine whether the indicators are more likely to serve as supporting or inhibiting factors in online mathematics learning. We also compared the results with findings from relevant previous studies to evaluate any consistency or divergence in the trends. This comprehensive analysis strategy aimed to provide a thorough understanding of the factors influencing online

mathematics learning during the COVID-19 pandemic, thereby contributing to the development of more effective educational practices in a digital context.

Results and Discussion

This study investigates the supporting and inhibiting factors affecting mathematics education students' experiences with online learning, focusing on eight crucial aspects: motivation, participation, course materials, facilities, online interaction, technological proficiency, learning environment, and self-regulation. The analysis revealed that students in Indonesia generally exhibited high motivation for online learning. Table 2 summarizes the specific findings, offering an overview of students' attitudes and highlighting the factors that either enhance or diminish their online learning experiences.

These results provide valuable insights into the key drivers of student engagement in an online educational environment, and they suggest that motivation plays a significant role in the success of online learning among mathematics education students. By examining the levels of motivation across various contexts, the research underscores the importance of cultivating a positive attitude toward online learning to enhance educational outcomes. Further analysis of the other aspects could reveal additional factors that contribute to or hinder online mathematics learning experiences.

Table 2. Analysis of student learning motivation during online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree
1.	(-) I am not excited about taking online classes.	11.6	29.7	48.7	10
2.	(+) I am still enthusiastic about learning online because the lecturer explains the material in an easy-to-understand way.	18.4	59.6	20.2	1.8
3.	(+) I still do my assignments seriously even though I study online.	50.4	44.2	4.8	0.6
4.	(-) I feel that online learning gives too much work, and the time is too limited.	20.4	43.6	34.1	1.9

Table 2 reveals that students are quite enthusiastic about online learning and demonstrate a strong commitment to engaging in and completing online course assignments (as indicated by statements 1–3). However, a majority of students express concerns about a lack of time for studying due to heavy workloads (statement 4), suggesting that while motivation and enthusiasm are high, the balance between academic tasks and available time could be a challenge.

Overall, the data reflect a positive attitude toward online learning among mathematics education students, with learning motivation emerging as a key supporting factor. The consistent interest in participating in online courses, despite the perceived workload challenges, underscores the students' resilience and adaptability.

Furthermore, Table 3, which focuses on students' participation, reinforces the notion that participation in online learning is generally positive. This indicates that students are not only motivated but are also actively engaging with online course activities. The combination of high motivation and active participation serves as a strong foundation for effective online learning in the mathematics education context. Further examination of other aspects, such as course materials, facilities, and online interaction, may provide a more comprehensive understanding of the dynamics at play in online mathematics education.

Table 3. Analysis of students' participation in online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree
5.	(-) I keep silent when I do not understand the presented material in online learning.	8.6	35.9	45.4	10.1
6.	(+) When I have difficulty, I will ask friends or lecturers via chat or direct comment during virtual meetings.	39.5	54.9	5.3	0.3
7.	(-) I feel lazy to engage in discussions during online classes and only listen to the lecturer's explanation.	4.2	23.1	55.8	16.9
8.	(+) I actively participate in online learning by asking and answering feedback given by the lecturer.	19.9	61.7	18.4	0

Table 3 demonstrates that students generally responded positively to the positive (+) statements, showing high agreement percentages. Conversely, the negative (-) statements received low agreement percentages, indicating that students tend to disagree with them. This pattern suggests that student participation in online learning is generally strong, reinforcing that it can be a supportive factor for implementing online mathematics learning.

The positive responses to the (+) statements indicate that students are actively engaging in online courses, participating in discussions, and completing assignments, which bodes well for the success of online mathematics education. This aligns with previous findings that highlighted the importance of student participation in achieving successful online learning outcomes.

Moving on to the third aspect, learning materials, the results presented in Table 4 will shed light on the adequacy and quality of the resources provided for online mathematics learning. These insights will be crucial in understanding whether learning materials act as supporting or inhibiting factors in the context of online education, especially in mathematics. By examining the students' responses to questions about learning materials, we can identify potential areas for improvement and suggest strategies to enhance the online learning experience.

Table 4. Analysis of lecture materials in online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree

9.	(-) Mathematical objects that are abstract and contain many formulas require in-depth explanations, so we find it difficult to follow in online learning.	41.2	46.3	11.9	0.6
10.	(-) The modules given by the lecturer in online mathematics learning will be confusing without a further discussion about the material.	33.5	50.7	14.8	1
11.	(+) Online lectures make it easier for me to access materials anytime and anywhere	31.7	54.9	11.9	1.5
12.	(+) It is easier for me to understand the material in online learning because I can easily collaborate with peers to expand my understanding of material content without any limitation of space and time.	9.8	38.4	48.6	3.2

According to Table 4, the analysis reveals a notable discrepancy in the responses to positive and negative statements. The high agreement percentages for negative statements (the 9th and 10th) suggest that students encounter difficulties with the provided learning materials, which might be due to the abstract and complex nature of mathematical concepts in online learning. The fact that the positive statement (the 12th) received less than 50% agreement reinforces the notion that students require more detailed explanations and discussions to fully grasp the material.

This outcome indicates that the learning materials aspect serves as an inhibiting factor in online mathematics learning. Although materials are available, their lack of detail or clarity may require students to seek additional support and clarification. This finding points to the need for enhanced instructional strategies, such as more interactive content, comprehensive explanations, or additional resources to help students understand abstract concepts in online mathematics education.

Turning to the facilities and infrastructure aspect, the results presented in Table 5 will help assess whether the technological resources, internet connectivity, and learning environments are adequate to support online learning. Understanding the impact of these elements will provide a clearer picture of the overall learning experience and identify other potential barriers to effective online mathematics education.

Table 5. Analysis of facilities and infrastructure in online learning

Item	Statements	Responses (%)			
		Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
13.	(+) I have a device (HP/Laptop) that is adequate to participate in online learning.	29.6	57	12.5	0.9
14.	(-) My cell phone/laptop has insufficient memory capacity to download various applications to support online learning, such as Google Classroom, Edmodo, zoom meetings, and other applications.	17.8	32.3	41.2	8.6
15.	(-) I find it challenging to carry out online learning because it needs a big internet quota.	21.3	40.4	34.7	3.6

16.	(+) I have sufficient Wi-Fi/internet quota to carry out online learning.	14.8	44.8	33.2	7.2

According to Table 5, it is clear that the facilities and infrastructure aspects present significant challenges for students in online mathematics learning. A significant number of students struggle to afford sufficient internet data (14th statement) and lack adequate device capacity to support online learning applications (15th statement). Although most students have access to smartphones or laptops (13th statement), the issues with internet access and device capability indicate that the facilities and infrastructure aspects act as an inhibiting factor in online mathematics learning.

This observation underscores the importance of addressing technology-related barriers to enhance the online learning experience for mathematics students. Addressing internet data affordability and providing access to devices with sufficient capacity would improve the overall efficacy of online education.

Regarding interaction, Table 6 highlights the limitations in communication and collaboration between lecturers and peers during online learning. These limitations pose challenges in understanding the course material, suggesting that the lack of interaction could be a significant barrier to effective learning. This finding aligns with other studies that have identified a need for increased interaction in online education, as it plays a crucial role in deepening understanding and fostering engagement.

The results suggest that enhancing interaction between students, lecturers, and peers could improve comprehension and overall learning outcomes. Strategies to boost interaction might include regular virtual office hours, breakout rooms for group discussions, and collaborative projects to encourage peer-to-peer learning. Addressing these limitations can lead to a more engaging and supportive online learning environment for mathematics education students.

Table 6. Analysis of students' interaction in online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree
17.	(+) Lecturers give good responses to students' questions during online lectures.	30.3	65.9	3.6	0.2
18.	(-) The limited space for interaction with lecturers in online learning makes it difficult to understand the material.	19	57.3	21.7	2
19.	(+) Online learning makes it easier for me to work with peers to complete group assignments.	9.5	40.4	45.7	4.4
20.	(-) The limitations in interacting with friends and lecturers made me unable to have a meaningful experience in the learning process.	27	49.9	22	1.1

According to Table 6, the majority of students acknowledge that limited interaction with lecturers and peers is a significant barrier to their online learning experience, with 76.9% agreeing with the negative statement that this limitation prevents them from engaging in the

"real" learning process (item 20). Additionally, the response to item 19 indicates that some students disagree with the notion that online learning supports effective collaboration for group assignments, suggesting that remote education may hinder teamwork and peer engagement.

The high agreement percentages with negative statements—76.3% for item 18 and 76.9% for item 20—underscore that interaction is an inhibiting factor in online mathematics learning. This limited interaction reduces opportunities for collaborative learning and direct feedback from lecturers, both of which are crucial for comprehending complex mathematical concepts.

The findings suggest a need to explore strategies to improve interaction in online learning settings. Options might include increasing synchronous sessions, creating smaller virtual groups for discussions, and encouraging more active communication between students and lecturers.

In terms of technological mastery, the results presented in Table 7 will help assess whether students have the necessary technical skills to effectively participate in online learning. The level of technological proficiency among students is a key factor in determining the success of online education, particularly in mathematics, where specialized software and digital tools are often required. Understanding this aspect will provide further insight into the barriers and enablers of effective online mathematics learning.

Table 7. Analysis of student technology skills mastery in online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree
21.	(+) I can operate applications for online learning such as Zoom, Webex, Google Classroom, Google Drive, or other LMS applications.	28.2	62.9	8.6	0.3
22.	(+) I can access online learning resources such as journals, e-books, and learning videos.	27.6	64.1	7.7	0.6
23.	(-) I do not know much about IT, so it is not easy to run various applications in online learning	3.9	30.3	55.5	10.4

According to Table 7, students generally exhibit strong technology skills, as evidenced by the high percentage of agreement with positive statements and low agreement with negative ones. The high levels of agreement with positive statements (items 21 and 22) suggest that students are proficient in operating various online learning applications, including Zoom, Webex, Classroom, and other Learning Management Systems (LMS). Additionally, students demonstrate the ability to access online learning resources effectively. The low agreement with negative statements (item 23) indicates that a significant portion of students do not face substantial difficulties with technology-related tasks.

Thus, technology skills emerge as a supporting factor in the implementation of online mathematics learning. This finding indicates that students are well-equipped to navigate digital platforms, suggesting that technological proficiency does not pose a barrier to their online education. It also suggests that efforts to improve online mathematics learning should focus on other areas, such as enhancing interaction or addressing infrastructural issues.

Next, the learning environment aspect, as presented in Table 8, will offer insights into the context in which students are engaging with online learning. The learning environment can significantly impact a student's ability to focus, interact, and effectively absorb educational content. Understanding the dynamics of students' learning environments can guide improvements in online education strategies to ensure they foster a conducive atmosphere for learning.

Table 8. Analysis of student learning environment for online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree
24.	(-) Due to social media, my focus is often distracted when listening to lecturers' explanations during online learning.	11.3	38	40.1	10.8
25.	(-) I am disturbed by the noisy environment at home when taking online classes.	24.3	42.5	28.2	5
26.	(-) Every time I have online lectures, I must leave the house because the internet signal is unstable.	12.4	25.8	49.6	12.2
27.	(-) I cannot fully concentrate on online learning at home because I sometimes help my parents.	22	39.5	32.9	5.6

Table 8 indicates that all the items are negative statements, with average agreement percentages exceeding 50%. This suggests that most students do not have a conducive environment for online learning. High agreement percentages with negative statements imply that factors like noise, lack of space, distractions, or other issues could be impacting students' ability to focus and engage effectively with online mathematics learning. This outcome suggests that the learning environment is an inhibiting factor for successful online mathematics education.

Given these results, efforts to improve online learning should consider strategies to help students create a more conducive environment at home or wherever they are learning. Potential solutions might include providing guidance on setting up a dedicated study space, reducing distractions, or offering tips for managing time and interruptions.

Regarding the final aspect, Table 9 presents results on self-regulated learning. This aspect is critical for online learning, as it involves students' ability to manage their own learning process, including setting goals, maintaining discipline, and managing time effectively. The insights from Table 9 will help determine whether self-regulation supports or hinders the online learning process, providing guidance on where students might need additional support or resources.

Table 9. Analysis of students' self-regulated learning during online learning

Item	Statements	Responses (%)			
		Strongly Agree	Agree	Disagree	Strongly Disagree

28.	(-) I procrastinate until the end of the deadline and rush to get the tasks done.	12.8	32.3	44.8	10.1
29.	(-) I cannot control my thoughts, emotions, and actions during online learning.	9.8	35.9	46.9	7.4
30.	(+) I prepare to study first before taking online lessons.	13.9	58.5	25.8	1.8
31.	(+) I have good time management during online learning.	11.3	59.9	26.4	2.4

According to Table 9, some students struggle with procrastination and find it difficult to control their thoughts, emotions, and actions during online learning, but they demonstrate effective time management and preparation for online learning (as indicated by statements 30 and 31). This suggests that, despite occasional issues with procrastination, students generally possess the skills and discipline required to successfully engage in self-regulated learning.

Overall, the findings indicate that self-regulated learning is a supportive factor in the context of online learning implementation. Students' ability to manage their time, prepare for online classes, and take responsibility for their learning reflects positively on the potential for successful online mathematics education. However, given the identified challenge of procrastination, it would be beneficial for educators to implement strategies that promote better focus and consistency in completing assignments.

Considering these findings, measures that promote self-regulated learning could enhance the overall online learning experience. These might include providing clear assignment deadlines, encouraging regular study routines, and offering resources on managing stress and improving focus. By enhancing students' self-regulated learning skills, educational institutions can create a more effective and supportive online learning environment.

Online learning has gained global prominence, offering a practical solution to overcome the time and distance constraints inherent in conventional education (Panigrahi et al., 2018). Over the years, it has become an effective method for teaching and learning, particularly during the COVID-19 pandemic, which necessitated a rapid shift to online platforms. Despite its many advantages, online learning also presents certain disadvantages. This study seeks to understand the experiences of students in online mathematics learning during the COVID-19 pandemic, focusing on both the supportive and inhibiting factors from the perspective of mathematics education students.

The research identifies four aspects that support the successful implementation of online mathematics learning in Indonesia: learning motivation, student participation, technology skills, and self-regulated learning. Learning motivation is a critical factor for embracing online learning, as it drives student engagement and persistence (Mahande & Akram, 2021). According to the survey results presented in Table 2, students have a strong motivation to participate in online mathematics learning, reinforcing its role as a supportive factor in Indonesian online education.

The survey results indicate that over 80% of students (Table 3) actively engage in online learning, frequently asking questions and providing feedback to their lecturers. Additionally, when they face challenges, students seek help from their peers or lecturers, either through chat

or direct comments during virtual meetings. This level of engagement aligns with Kuo et al.'s (2014) findings, which suggest that online learning can promote active participation as the virtual environment reduces the pressure of speaking publicly, potentially lowering feelings of shame and fear. Research by Leslie (2020) and Muslih et al. (2021) further supports the idea that online learning can encourage more student interaction and participation.

Despite this active participation, there are challenges with the lecture material. According to Table 4, 87.5% of students find it difficult to understand abstract mathematical concepts and formulas in an online learning context, indicating a need for clearer explanations from instructors. This difficulty aligns with earlier research (Bringula et al., 2021), which noted the unique challenges of teaching mathematics online due to its abstract nature. Online formats, where traditional face-to-face methods for teaching and clarification are limited, can compound the complexities of abstract patterns in mathematical problem-solving. This finding suggests that while students may be motivated and actively engaged, there is a need for more robust support in conveying complex mathematical content in an online environment.

Moreover, the survey results indicate that a significant portion of students, 61.7% (Table 5), experience unstable or unavailable internet access due to the high cost, making facilities and infrastructure an inhibiting factor for online mathematics learning. The limited internet access is influenced by students' financial readiness, with some students needing to budget carefully to afford internet data alongside other daily expenses. The economic impact of the COVID-19 pandemic, which resulted in job losses and reduced income for many families, exacerbates this financial strain (Mulyana et al., 2020). These findings are consistent with research by Mailizar et al. (2020), who reported that high internet costs created barriers for students in online learning environments outside China.

Interaction between students and lecturers also poses a challenge in online learning. According to Table 6, 76.9% of students report low interaction with their peers and lecturers, hindering their ability to fully engage in the learning process. Demuyakor (2020) emphasizes that online learning systems tend to reduce social interaction, leading to lower academic outcomes and decreased social control. This lack of interaction is partly due to the rapid transition to online learning during the COVID-19 pandemic, which caught lecturers and students unprepared. Lecturers may not have had sufficient time to plan and develop effective online learning designs, and students might have struggled with the abrupt shift from traditional learning methods. As a result, boredom and frustration became common, as noted by Setiawan & Aden (2020).

Overall, these findings suggest that addressing the high cost of internet data and improving interaction in online mathematics learning are crucial. Institutions can explore ways to reduce the financial burden on students, such as offering subsidies or partnerships with internet providers. Additionally, creating more interactive online learning experiences and providing adequate training and support to lecturers can help foster better student engagement and mitigate the drawbacks of a rapid shift to online education.

Furthermore, most students do not face significant barriers in terms of technological skills for online learning, with only 34.2% (Table 7) indicating they have difficulty operating various

online learning applications. This suggests that technology skills are generally a supportive factor for online mathematics learning. The success of online education relies on supporting facilities, such as smartphones, laptops, or tablets, that enable students to access learning materials from anywhere (Gikas & Grant, 2013). The effective use of the internet and multimedia technology can transform knowledge dissemination and serve as a classroom learning alternative (Zhang et al., 2004).

However, the learning environment poses challenges to online education. According to Table 8, 66.8% of students agree that the home environment can be noisy and distracting during online classes, preventing optimal learning. Other obstacles include unstable networks and indiscipline in managing online learning due to competing demands from home activities. These findings align with research by Baticulon et al. (2021), indicating that key obstacles to online learning include issues with internet connectivity, financial constraints, and home-related disruptions. Students often struggle with studying at home due to noise, distractions, and limited space, which can negatively impact focus and concentration.

To address these issues, universities and educators need to consider strategies that improve the learning environment for students. This might involve providing tips for creating a dedicated study space, promoting discipline in managing online learning, and offering flexible learning options to accommodate varying home environments. Addressing technological skill gaps and improving the learning environment can play a crucial role in enhancing the effectiveness of online mathematics education.

Meanwhile, in terms of self-regulated learning, most students responded positively to the survey results, indicating that they prepare for online classes by studying beforehand and demonstrating good time management. However, 45.1% (Table 9) of students still tend to procrastinate on assignments, typically completing them at the last minute. This behavior may result from students spending time on other activities, such as playing games, chatting on social media, watching TV, or other distractions, leading to less effective learning and a failure to master key concepts. As a result, students may struggle to produce high-quality work, as they might not push themselves to explore the provided materials or delve deeper into the subject.

To address these obstacles, particularly those related to learning materials and student interaction, educators can take several approaches. Lecturers should allocate sufficient time for lectures, use multimedia for content delivery, and create a more enjoyable and interactive learning atmosphere. Anugrahana (2020) emphasizes the importance of creativity and innovation in designing engaging online learning experiences. Utami & Cahyono (2020) suggest implementing interactive and engaging teaching methods and optimizing technology to enhance online mathematics learning.

Additional strategies that could support self-regulated learning include collecting feedback from students to understand their needs, organizing group discussions, allowing longer-duration exercises to promote deeper engagement, and offering asynchronous consultation sessions for personalized support. Furthermore, family support and understanding are crucial for fostering a conducive learning environment at home. Government efforts to develop internet infrastructure and reduce the cost of online learning resources could also play

a significant role in enabling a better online learning experience for students. Finally, by adopting these strategies, lecturers can mitigate some of the challenges associated with online mathematics learning, promote more effective self-regulated learning, and encourage greater student engagement and success in an online educational setting.

Conclusion

From the students' perspective, this study found that several factors play a supportive role in implementing online mathematics learning in Indonesia. These supportive aspects include high student motivation, active student participation, sufficient technological skills, and effective self-regulated learning. These factors contribute to a positive online learning experience, indicating that students are engaged and capable of managing their online education.

However, the study also identified several inhibiting factors in online mathematics learning. These include unstable internet access and high data requirements, which limit connectivity, complex learning materials that demand clearer explanations, limited interaction between students and lecturers, and an inadequate learning environment due to noise and distractions at home. These barriers can hinder the effectiveness of online learning and reduce student engagement.

The insights from this study can guide instructors in the mathematics education program to design interactive online learning that is both engaging and comprehensible. Recommendations for educators include utilizing multimedia tools for content delivery, creating an enjoyable learning atmosphere, and promoting a more interactive classroom experience. Instructors should also address connectivity issues and explore ways to improve student-lecturer interaction to foster a more conducive online learning environment.

Additionally, this study opens the door to further research that examines the supporting and inhibiting factors in online mathematics education from the lecturers' perspective. Comprehensive insights from both students and instructors would offer a well-rounded understanding of the challenges and opportunities in online mathematics learning. Such research could contribute to enhancing the overall quality of online education and guide future pedagogical strategies for more effective and inclusive online mathematics education.

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Conflicts of Interest

The authors declare that here is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been covered completely by the authors.

References

Almarashdi, H., & Jarrah, A. M. (2021). Mathematics distance learning amid the covid-19 pandemic in the UAE: High school students' perspectives. *International Journal of Learning, Teaching and Educational Research*, *20*(1), 292-307. https://doi.org/10.26803/ijlter.20.1.16

Anugrahana, A. (2020). Hambatan, solusi dan harapan: Pembelajaran daring selama masa pandemi covid-19 oleh guru Sekolah Dasar. *Scholaria: Jurnal Pendidikan dan Kebudayaan*, *10*(3), 282-289. https://doi.org/10.24246/j.js.2020.v10.i3.p282-289

Ariyanti, G. & Santoso, F. G. I. (2020). The effects of online mathematics learning in the covid-19 pandemic period: a case study of senior high school students at Madiun City, Indonesia. *Mathematics Teaching Research Journal Fall*, *12*(3). 4-11. Retrieved from https://commons.hostos.cuny.edu/mtrj/wp-content/uploads/sites/30/2020/10/v12n3-The-Effects-of-Online-Mathematics-Learning.pdf

Arkorful, V., & Abaidoo, N. (2014). The role of e-learning, the advantages and disadvantages of its adoption in Higher Education. *International Journal of Education and Research*, *2*(12). 29-42. Retrieved from https://www.ijern.com/journal/2014/December-2014/34.pdf

Basilaia, G., & Kvavadze, D. (2020). Transition to online education in schools during a SARS-CoV-2 coronavirus (COVID-19) pandemic in Georgia. *Pedagogical Research*, *5*(4), 1–9. https://doi.org/10.29333/pr/7937

Baticulon, R. E., Sy, J. J., Alberto, N. R. I., Baron, M. B. C., Mabulay, R. E. C., Rizada, L. G. T., Tiu, C. J. S., Clarion, C. A., & Reyes, J. C. B. (2021). Barriers to online learning in the time of COVID-19: A national survey of medical students in the Philippines. *Medical Science Educator*, *3*, 615–626. https://doi.org/10.1007/s40670-021-01231-z

Bower, M., Dalgarno, B., Kennedy, G. E., Lee, M. J. W., & Kenney, J. (2015). Design and implementation factors in blended synchronous learning environments: Outcomes from a cross-case analysis. *Computers and Education*, *86*. 1–17. https://doi.org/10.1016/j.compedu.2015.03.006

Bringula, R., Reguyal, J. J., Tan, D. D., & Ulfa, S. (2021). Mathematics self-concept and challenges of learners in an online learning environment during covid-19 pandemic. *Smart Learning Environment*, *8*(22), 1-23. https://doi.org/10.1186/s40561-021-00168-5

Callaway, S. K. (2012). Implications of online learning: Measuring student satisfaction and learning for online and traditional students. *Insights to a Changing World Journal*, *2*, 67-94.

Cassibba, R., Ferrarello, D., Mammana, M. F., Musso, P., Pennisi, M., & Taranto, E. (2020). Teaching mathematics at distance: A challenge for universities. *Education Sciences*, *11*(1), 1-20. http://doi.org/10.3390/educsci11010001

Demuyakor, J. (2020). Coronavirus (Covid-19) and online learning in Higher Institutions of Education: A survey of the perceptions of Ghanaian International Students in China. *Online Journal of Communication and Media Technologies*, *10*(3), 1-9. https://doi.org/10.29333/ojcmt/8286

Enu, J., Agyman, O. K., & Nkum, D. (2015). Factors influencing students' mathematics performance in some selected colleges of education in Ghana. *International Journal of Education Learning and Development*, *3*(3), 68-74. Retrieved from http://www.eajournals.org/wp-content/uploads/Factors-Influencing-Students-Mathematics-Performance-In-Some-Selected-Colleges-Of-Education-In-Ghana.pdf

Fabito, B. S., Trillanes, A. O., & Sarmiento, J. R. (2021). Barriers and challenges of computing students in an online learning environment: Insights from one private university in the Philippines. *International Journal of Computing Sciences Research*, *5*(1), 441–458. https://doi.org/10.25147/ijcsr.2017.001.1.51

Geary, D.C., Berch, D.B., & Koepke, K.M. (2019). *Cognitive foundations for improving mathematical learning*. San Diego: Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-815952-1.00001-3

Gikas, J., & Grant, M. M. (2013). Mobile computing devices in higher education: student perspectives on learning with cellphones, smartphones & social media. *Internet and Higher Education*, *19*, 18-26. https://doi.org/10.1016/j.iheduc.2013.06.002

Himmi, N., Agustyaningrum, N., & Iswanti, I. (2021). Analisis permasalahan pembelajaran daring selama pandemi covid-19 ditinjau dari pemahaman konsep matematika siswa SMK. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(4), 2497-2506. https://doi.org/10.24127/ajpm.v10i4.4229

Huang, R., Tlili, A., Chang, T. W., Zhang, X., Nascimbeni, F., & Burgos, D. (2020). Disrupted classes, undisrupted learning during COVID-19 outbreak in China: Application of open educational practices and resources. *Smart Learning Environments*, *19*(7), 1-15, https://doi.org/10.1186/s40561-020-00125-8

Irfan, M., Kusumaningrum, B., Yulia, Y., & Widodo, S.A. (2020). Challenges during the pandemic: Use of e-learning in mathematics learning in Higher Education. *Infinity*, *9*(2), 147-158. https://doi.org/10.22460/infinity.v9i2.p147-158

Kamsurya, R. (2020). Learning evaluation of mathematics during the pandemic period covid-19 in Jakarta. *International Journal of Pedagogical Development and Lifelong Learning*, *1*(2), ep2008. https://doi.org/10.30935/ijpdll/8439

Kemendikbud. (2013). *Permendikbud No. 109 tentang Penyelenggaraan Pendidikan Jarak Jauh pada Pendidikan Tinggi*. Jakarta: Kementrian Pendidikan dan Kebudayaan. Retrieved from https://peraturan.go.id/files/bn1580-2013.pdf

Kuo, Y.C., Walker, A.E., Schroder, K.E.E., & Belland, B.R. (2014). Interaction, internet self-efficacy, and self-regulated learning as predictors of student satisfaction in online education courses. *The Internet and Higher Education*, *20*, 35-50. https://doi.org/10.1016/j.iheduc.2013.10.001

Leedy, P. D., & Ormrod, J. E. (2016). *Practical research: Planning and design (Eleventh edition)*. London: Pearson.

Leslie, H.J. (2020), Trifecta of student engagement: A framework for an online teaching professional development course for faculty in higher education. *Journal of Research in Innovative Teaching & Learning*, *13*(2), 149-173. https://doi.org/10.1108/JRIT-10-2018-0024

Levy, S., & Goldfarb, L. (2021). The perception of subset quantity and items in an environment with distractors in a population with mathematical learning difficulties. *Trends in Neuroscience and Education*, *25*, 100166. https://doi.org/10.1016/j.tine.2021.100166

Lisnani, L., & Tanujaya, B. (2021). Respon mahasiswa terhadap perkuliahan online pada pembelajaran matematika di masa pandemi COVID-19. *Journal of Honai Math*, *4*(1), 67-84. https://doi.org/10.30862/jhm.v4i1.177

Mahande, R. D., & Akram. (2021). Motivational factors underlying the use of online learning system in higher education: An analysis of measurement model. *Turkish Online Journal of Distance Education-TOJDE*, *22*(1), 89-100. https://doi.org/10.17718/tojde.849888

Mailizar, M., Almanthari, A., Maulina, S., & Bruce, S. (2020). Secondary school mathematics teachers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(7), 1-9. https://doi.org/10.29333/ejmste/8240

Means, B. (2010). Technology and education change: Focus on student learning. *Journal of Research on Technology in Education*, *42*(3), 285-307, https://doi.org/10.1080/15391523.2010.10782552

Moore, J. L., Dickson-Deane, C., & Galyen, K. (2011). E-learning, online learning, and distance learning environments: Are they the same?. *Internet and Higher Education*, *14*(2), 129–135. https://doi.org/10.1016/j.iheduc.2010.10.001

Moreno-Guerrero, A.J., Aznar-Díaz, I., Cáceres-Reche, P., & Alonso-García, S. (2020). E-learning in the teaching of mathematics: An educational experience in Adult High School. *Mathematics*, *8*, 1-16. https://doi.org/10.3390/math8050840

Mulyana, et al. (2020). Information literacy training on the preparedness of Garut people in facing landslide threats. *Indonesian Journal of Community Empowerment*, *1*(1), 11-20.

Muslih, Y. N., Komalasari, I., & Haimah, A. H. (2021). Students' participation in online learning during covid-19 pandemic in East Priangan. *Lentera Pendidikan: Jurnal Ilmu Tarbiyah dan Keguruan*, *24*(2), 276-289. https://doi.org/10.24252/lp.2021v24n2i10

Nakamura, Y., Yoshitomi, K., Kawazoe, M., Fukui, T., Shirai, S., Nakahara, T., Kato, K., & Tetsuya Taniguchi. (2018). Effective use of math e-learning with questions specification. *International Trends in Research and Development*, 133-148. https://doi.org/10.1007/978-3-319-90790-1

Onyema E. M., Eucheria N. C., Obafemi F. A., Sen S., Atonye F. G., Sharma A., and Alsayed A. O. (2020). Impact of coronavirus pandemic on education. *Journal of Education and Practice*, *11*(13), 108-121. https://doi.org/10.7176/JEP/11-13-12

Özyurt, Ö., Özyurt, H., Baki, A., & Güven, B. (2013). Integration into mathematics classrooms of an adaptive and intelligent individualized e-learning environment: Implementation and evaluation of Uzwebmat. *Computers in Human Behavior*, *29*(3), 726-738. https://doi.org/10.1016/j.chb.2012.11.013

Panigrahi, R., Srivastava, P. R., & Sharma, D. (2018). Online learning: adoption, continuance, and learning outcome: a review of literature. *International Journal Information Manage*, *43*, 1–14. https://doi.org/10.1016/j.ijinfomgt.2018.05.005

Salac, R. A., & Kim, Y. S. (2016). A Study on the internet connectivity in the Philippines. *Asia Pacifc Journal of Business Review*, *1*(1), 67–88. https://doi.org/10.20522/APJBR.2016.1.1.67

Setiawan, T.H., & Aden. (2020). Efektifitas penerapan blended learning dalam upaya meningkatkan kemampuan akademik mahasiswa melalui jejaring schoology di masa pandemi covid-19. *Jurnal Pembelajaran Matematika Inovatif*, *3*(5), 493-506. https://doi.org/10.22460/jpmi.v3i5.p%25p

Shahzad, A., Hassan, R., Aremu, A. Y., Hussain, A., & Lodhi, R. N. (2021). Effects of COVID-19 in e-learning on Higher Education Institution students: The group comparison between male and female. *Quality & Quantity*, *55*(3), 805-826. https://doi.org/10.1007/s11135-020-01028-z

Siddiqui, S., & Singh, T. (2016). Social media its impact with positive and negative aspects. *International Journal of Computer Applications Technology and Research*, *5*(2), 71 - 75. Retrieved from https://www.ijcat.com/archives/volume5/issue2/ijcatr05021006.pdf

Singh, V., & Thurman, A. (2019). How many ways can we define online learning? A systematic literature review of definitions of online learning (1988-2018). *American Journal of Distance Education*, *33*(4), 289-306. https://doi.org/10.1080/08923647.2019.1663082

Utami, Y. P., & Cahyono, D. A. D. (2020). Study at home: analisis kesulitan belajar matematika pada proses pembelajaran daring. *Jurnal Ilmiah Matematika Realistik*, *1*(1), 20–26. https://doi.org/10.33365/ji-mr.v1i1.252

Varalakshmi, R., & Arunachalam, K. (2020). COVID 2019 – Role of faculty members to keep mental activeness of students. *Asian Journal of Psychiatr*, *51*, 102091. https://doi.org/10.1016/j.ajp.2020.102091

Wijaya, T. T. (2021). How Chinese students learn mathematics during the coronavirus pandemic. *International Journal of Educational Research and Innovation*, *15*, 1-16. https://doi.org/10.46661/ijeri.4950

Yohannes, Y., Juandi, D., Diana, N., & Sukma, Y. (2021). Mathematics teachers' difficulties in implementing online learning during the COVID-19 pandemic. *Journal of Hunan University Natural Sciences*, *48*(5), 87–98. Retrieved from http://jonuns.com/index.php/journal/article/view/581

Zaharah, Z., Kirilova, G. I., & Windarti, A. (2020). Impact of corona virus outbreak towards teaching and learning activities in Indonesia. *SALAM: Jurnal Sosial Dan Budaya Syari*, *7*(3), 269–282. https://doi.org/10.15408/sjsbs.v7i3.15104

Zaki, R. (2017). Validation of instrument measuring continuous variable in medicine. In *Advances in Statistical Methodologies and Their Application to Real Problems*. InTech. https://doi.org/10.5772/66151

Zhang, D., Zhao, J. L., Zhou, L., & Nunamaker, J. F. (2004). Can e-learning replace classroom learning? *Communications of the ACM*, *47*(5), 75-79. https://doi.org/10.1145/986213.986216