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The Effectiveness of Online Mathematics Learning during Covid-19: Empirical Evidence from a Tertiary Institution in Ghana

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Abstract

The Covid-19 pandemic prompted a global shift to online education, posing unique challenges for mathematics instruction. This study investigates undergraduate mathematics students' perceptions of the effectiveness of online teaching strategies and the challenges they faced during the Covid-19 era. With the pragmatic paradigm and sequential explanatory design, data were collected through questionnaires and interviews. Quantitative data were analyzed using descriptive statistics, while qualitative data were analyzed through content analysis. A simple random sampling technique was used to select 379 third-year mathematics students from Ghana's central region. The findings revealed that the combination of video, audio, and text-based materials was perceived as the most effective instructional strategy, while limited interaction between lecturers and students was the least effective. The primary challenge identified was limited internet access, significantly hindering online learning experiences. The study highlights the importance of understanding students' perceptions to enhance online mathematics learning. It concludes that effective online instructional strategies are crucial for successful mathematics education. The study recommends continuous training for mathematics lecturers on effective online teaching methods, improved network connectivity from the telecommunication sector, and universities providing data-free access to online platforms to address internet challenges.

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INTRODUCTION

The onset of Covid-19 saw rapid growth in online learning worldwide since it became the main avenue for continuous teaching and learning amid the pandemic (Adedoyin & Soykan, 2020). The shift to online learning by most educational institutions has necessitated more research to be conducted in this area. The global pandemic of Covid-19 has also prompted an extraordinary response in education to investigate the practical and pedagogical issues of meeting students' learning requirements during difficult times. Online learning comes with challenges, such as students feeling isolated, a lack of technical equipment such as computers and tablets for studies, and technical issues involving software usage and internet access. Notwithstanding, online learning allows students to learn on the go irrespective of their location, has flexible learning hours, and allows individual learning patterns where students learn at their own pace.

In online learning, education takes place on the Internet using Information and Communication Technology (ICT) tools and platforms, such as videos, audio text, Zoom, Google Classroom, and

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Learning Management Systems (LMS) (Juhji et al., 2022; Priadi et al., 2021). Asynchronous and synchronous tools are used to communicate with students in online courses. Pictures or PDF scans of work on assigned issues are sent through email or the LMS for asynchronous interaction, and feedback is provided. At the same time, Zoom and videoconferencing technology are used to conduct synchronous interactions (Mukhtar et al., 2020). While both have administrative challenges, the asynchronous model avoids the problems caused by different calendars and allows students to enroll in two classes simultaneously (Mukhtar et al., 2020). This idea is conceivable because asynchronous learning involves learning at different times and locations. Also, most asynchronous learning environments make teaching materials available online, which students read before participating in online discussion forums. On the contrary, Synchronous learning occurs in real time with students and instructors attending together in different locations. According to (Yang et al., 2023), when properly blended, synchronous and asynchronous e-learning technologies can aid teachers and students in achieving effective course outcomes.

Social interaction has a considerable favorable impact on the effectiveness of online learning (Baber, 2022). Animations, digital collaborations with peers, video lectures delivered by faculty handling the subject, online quizzes with multiple-choice questions, availability of student version software, a conducive environment at home, interactions by faculty during lectures, and online materials provided by faculty were discovered to promote effective online learning (Darius et al., 2021). Also, online learning would be more effective if paired with other learning platforms and in-person instruction (Fatmahanik, 2021; Selco & Habbak, 2021). For instance, Google Classroom and YouTube are useful tools for teaching mathematics and can be used as a substitute for online instruction.

Student satisfaction in an online course is linked to clear assignment rules, rubrics, constructive comments, and the professor's (or course instructor's) content competence (Lee, 2014). The abstract nature of mathematics and the lack of helpful and visible instructors to address students' issues present obstacles to distant and online mathematics learning, necessitating improvements in the design, production, and availability of mathematics course materials and programs (Reju & Jita, 2018). Mathematics mostly deals with assumptions rather than actual objects. Learning mathematics also depends on following a logical sequence rather than observation and using mathematical symbolism and language. It is, therefore, imperative to use strategies that would enhance comprehension of the subject when learning online.

The Internet has a possible method to improve the quality of learning experiences and results, not merely as a delivery medium, and with the outbreak of Covid-19, new opportunities and challenges have been presented to students and faculty in teaching and learning mathematics online. The statistics show that advanced technology and the Internet alone were insufficient in assisting many students and instructors in adjusting to the lockdown situation. Moreover, Radmehr & Goodchild, (2022) postulated that immediate community collaboration is needed to address these difficulties and better prepare for online mathematics teaching and learning in higher education. Thus, lecturers and school management have a role in instructional delivery to make the teaching and learning of online mathematics successful. The instructors need to prepare teaching and learning materials and present them in ways that will enhance interaction, critical thinking, and understanding. Also, equipment for easy presentation should be used to enhance the presentation. Management should ensure that students and lecturers can access equipment to enhance online mathematics learning.

Studies conducted in the area of learning mathematics online and challenges in learning mathematics online include Trenholm & Peschke, (2020), who conducted a study in Canada and New York and found that issues communicating mathematical ideas in an online setting are predicted to prevail while new tools (such as MathML and Maple TA) are developing to assist overcome these obstacles. Johns & Mills, (2021) suggested that synchronous video conferencing with a shared whiteboard is the ideal format for online tutoring. Again, Google Classroom is a useful tool for teaching mathematics and can be used as a substitute for online instruction. However, it would be more effective if paired with other learning platforms and in-person instruction (Fatmahanik, 2021).

Huda et al., (2021) discovered that students have a favorable opinion of online mathematics learning through YouTube, and there is a positive relationship between students' perceptions and learning achievement. The inability to write mathematical symbols and the basic constraints of learning management systems and multimedia software to support online learning must be overcome (Irfan et al., 2020). Similarly, due to numerous issues that arise when taking online classes, including lack of motivation, lack of comprehension of the material, a decline in communication between the students and their instructors, and a sense of isolation brought on by taking online classes, students continue to prefer classroom instruction over online learning (Alawamleh et al., 2020). Therefore, it is imperative to conduct an empirical study to determine undergraduate students' perception of the effectiveness of learning strategies employed in learning mathematics online in the Covid-19 era.
This study aimed to determine undergraduate mathematics students' perception of the effectiveness of strategies in learning mathematics online in the Covid-19 era. The study was guided by the research questions: (1) What is undergraduate mathematics students' perception of the effectiveness of the online instructional delivery strategies they experienced during the Covid-19 era? (2) What challenges inhibit mathematics students' online learning effectiveness during the Covid-19 era?

METHOD

The sequential explanatory design was employed in this study to gain a broader and more in-depth understanding of undergraduate mathematics students' perception of the effectiveness of the online instructional delivery strategies they experienced during the Covid-19 era. The sequential explanatory design is a two-phase mixed method with quantitative and qualitative phases. The quantitative data was collected and analyzed first; then, qualitative data was collected and analyzed based on the quantitative results. This strategy aimed to collect quantitative data augmented by qualitative data to produce more trustworthy and valid results (McCusker & Gunaydin, 2015). The figure below shows the flowchart of the sequential explanatory mixed-method design employed in the study.

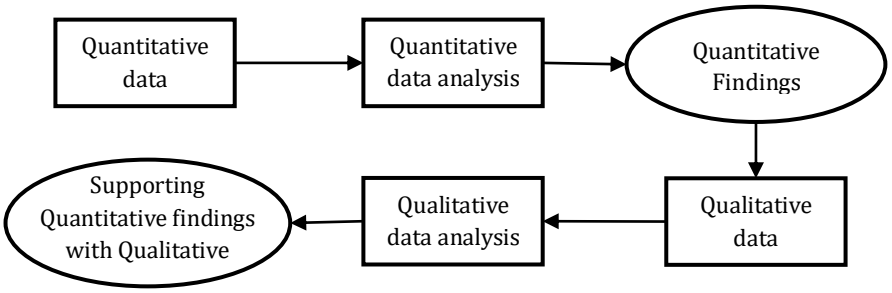

Figure 1. The Flowchart of the Sequential Explanatory Mixed-Method Design

The quantitative data was employed in this study to determine undergraduate mathematics students' perception of the effectiveness of strategies employed in online instructional delivery and the challenges undergraduate mathematics students faced in learning online in the era of Covid-19. Conversely, qualitative data was applied to investigate how these events occur and how students describe them.

The participants were three hundred and seventy-nine (379) third-year undergraduate mathematics students who were purposively sampled within the central region of Ghana. The sample included three hundred and three (303) males and seventy-four (74) females. All of them were undergraduate mathematics students who experienced online instructional delivery during the Covid-19 era. Again, four (4) students were further selected from the sample and interviewed using a simple random sampling technique to give more insight into certain areas of students' perceptions of the effectiveness of strategies used in learning mathematics online and challenges that inhibited their online learning.

Questionnaires and interviews were used to collect data for this study. These instruments were found to be appropriate for answering the research questions for this study. The questionnaire was designed to mainly address the quantitative phase of the study. The questionnaire used a 5-point Likert scale. A Likert-type questionnaire was utilized since it is one of the most extensively used strategies for measuring perceptions (Ho, 2016).

Table 1. Likert Scale

Scale	Response
1	Strongly Disagree (SA)
2	Disagree (D)
3	Uncertain (U)
4	Agree (A)
5	Strongly Agree (SA)

The questionnaire comprised 15 items soliciting information on the following: mathematics students' perception (rating) of the effectiveness of online instructional delivery strategies in the Covid-19 period (8 items) and challenges faced by students in learning mathematics online during the Covid-19 period (7 items). On the other hand, semi-structured interviews aided the qualitative phase of this mixed-method study. Questions for the interview were mostly open-ended in nature.

Mathematics lecturers with in-depth knowledge of online learning and a researcher assisted in determining if the items were related to the study questions, and their ideas aided in establishing the items' face and content validity. Cronbach alpha values for items indicating students' experience with online instructional delivery were 0.849. The reliability coefficients from the pilot study confirm (Sekaran & Bougie, 2013) assertion that Cronbach alpha values less than 0.60 are deemed poor, those in the 0.70 range are acceptable, and those over 0.80 are considered high.' As a result of the preceding, the instrument was deemed reliable and valid for the primary data collection.

Before distributing the questionnaire, permission was sought from the university authorities where the study was conducted. Approval was obtained from the head of the department before contacting the students for the study. The purpose of the study was made known to the students before the questionnaire was administered to those willing to answer them. It should be noted that the researcher personally administered the questionnaires to 379 third-year mathematics education students out of 470 students, representing a response rate of 80.64%. Also, a face-to-face interview was conducted with four (4) students. After the data had been compiled, it was analyzed using the IBM SPSS Statistic, version 26, to address the quantitative aspect. The research questions, which sought to determine mathematics students' perception of the effectiveness of the online instructional delivery strategies and challenges encountered in learning mathematics online, were analyzed using descriptive statistics such as percentages, means, and standard deviations. The study's semi-structured interviews were tape-recorded verbatim and afterward transcribed. The collected data were then organized into themes based on the following themes: instructional delivery strategies and challenges encountered in learning mathematics online. The discussion on the effectiveness of instructional delivery strategies employed looked at students' interaction with lecturers and classmates and whether they enjoyed studying mathematics online.

RESULTS AND DISCUSSION

The foundation of the study is based on Anderson's Online Model. The theory is chosen because of its emphasis on the interaction between two main human actors, teachers and students, and their interaction with each other and with content. Terry Anderson examines learning theory in general and concentrates on intriguing aspects of online learning. In this model, students and teachers are the two main human players, and their interactions with one another and content are important. Students can interact directly with knowledge from different media, particularly on the Web (YouTube, etc.). Still, many prefer to have their learning sequenced, directed, and evaluated with the help of a teacher. This contact can happen within a community of inquiry, employing a variety of

synchronous and asynchronous Net-based activities. Students interact with each other by forming groups where they communicate to do assignments and learn. These environments are exceptionally rich, allowing for the development of social skills, collaborative subject acquisition, and the formation of personal ties among members.

On the other hand, the community bonds students in time, requiring frequent sessions or, at the very least, group-paced learning (Anderson, 2011). Here, students have their learning by downloading notes and videos on the topic to learn on their own. Students may also take drills to test their understanding of concepts.

This section discusses data from the field to address the research questions formulated to guide the study.

The First Research Question: What Is Mathematics Students' Perception of the Effectiveness of the Online Instructional Delivery Strategies They Experienced during the Covid-19 Era?

The first research question sought to determine mathematics students' perception of the effectiveness of the online instructional delivery strategies they experienced during the Covid-19 era. The effectiveness of the instructional delivery strategies was gauged by the respondents' ratings of their agreement/disagreement with certain selected instructional delivery strategies. The results in Table 2 and the responses from the interview that follow were used to address the research question.

Table 2. Students' Rating of Their Agreement with the Effectiveness of Online Instructional Delivery during the Covid-19

Items	SD (%)	Df (%)	Uf (%)	Af (%)	Saf (%)	Mean	Std. Dev
Lecturers combine video, audio, and text-based materials in online mathematics lessons	9(2)	18(5)	52(14)	175(46)	125(33)	4.03	0.934
There is very little interaction between lecturers and students in online mathematics lessons	32(9)	56(15)	50(13)	119(31)	122(32)	3.64	1.296
I have easy access to learning materials for online lessons	10(3)	52(14)	84(22)	161(42)	72(19)	3.61	1.026
Lecturers' explanations of mathematical concepts in online lessons are cumbersome (unclear)	25(6)	74(20)	79(21)	95(25)	106(28)	3.48	1.265
The course materials (text, audio, video) are well-developed for my understanding of mathematical lessons online	13(3)	78(20)	101(27)	127(34)	60(16)	3.38	1.083
The contents covered in the courses are satisfactory for the period mandated to complete the coursework	33(9)	59(16)	81(21)	153(40)	53(14)	3.35	1.160
The course materials provided are insufficient for learning mathematics online	34(9)	67(18)	100(26)	101(27)	77(20)	3.32	1.232
The course materials provided for online mathematics lessons are very interactive	25(7)	57(15)	115(30)	145(38)	37(10)	3.30	1.050
Overall rating						**3.51**	**0.470**

Source: Field survey, 2022

Table 2 shows that the online instructional delivery strategy that the students rated (or perceived) as the most effective with mean and standard deviation (M = 4.03, SD = 0.934) was "lecturers combine video, audio, and text-based materials in online mathematics lessons," which 79% of the students agreed was the most effective online instructional delivery strategy that supported their online learning. The second strategy they perceived as most effective in their online learning with mean and standard deviation (M= 3.61, SD = 1.026) is "I have easy access to learning materials for online lessons."

The students, however, had mixed opinions about the effectiveness of the following strategies: "Lecturers' explanation of mathematical concepts in online lessons are cumbersome (unclear)" (M = 3.48, SD = 1.265); "The course materials (text, audio, video) are well developed for my understanding of mathematical lessons online" (M = 3.38, SD = 1.083); "The contents covered in the courses are satisfactory for the period mandated to complete the course work" (M = 3.35, SD = 1.160) and "The course materials provided are insufficient for learning of mathematics online" (M = 3.32. SD=1.232). Thus the bottom two strategies that the students perceived (rated) as least effective in supporting their online learning were: (i) there is very little interaction between lecturers and students in online mathematics lessons, and (ii) The course materials provided for online mathematics lessons are very interactive. The overall mean and standard deviation of their perception of the effectiveness of the online instructional delivery strategies were (M = 3.51, SG = 0.470). Because 3.5 is the lower boundary of the 'agree-point' on the 5-point Likert scale used for the instrument, one can argue that the students marginally agreed that the delivery strategies were effective, and their responses clustered around the mean.

The findings on lecturers combining video, audio, and text-based materials in online mathematics lessons", which 79% of the students agreed were the most effective online instructional delivery strategy, corroborates with the findings of (Darius et al., 2021) that animations, video lectures delivered by faculty handling the subject were discovered to promote effective online learning. The findings on the interaction between lecturers and students in online mathematics lessons corroborate previous studies by (Almarashdi & Jarrah, 2021), who found that the strategy that students perceived as the most ineffective online strategy they experienced in learning mathematics online was missing the interaction with teachers and colleagues. Again, it confirms the assertion by (Darius et al., 2021) that interactions by faculty during lectures and online materials provided by faculty were discovered to promote effective online learning. The students had mixed opinions concerning the effectiveness of the instructional delivery strategies they experienced, confirming the findings of (Almarashdi & Jarrah, 2021), who found that students had mixed opinions about their experiences with online mathematics learning.

The researcher further interviewed students on online instructional delivery to gain deeper insight into the study. When asked whether they can interact effectively with their instructors? (Probing for How and Examples), the interviewees gave the following responses:

Kwesi said,

> *"Yes, I could interact with my lecturers sometimes during live lessons on Zoom and Google Classroom. For the non-live sessions, I interacted with my lecturers by posting questions on the Moodle forum, and the lecturer responded to them later."*

Esi responded that,

> *"I believe no because, during the lessons, I sometimes had pressing issues to ask, but because of the time allocated for the lesson and network challenges, I could not ask. Even though there was an option to ask your questions later after the class for the lecturers to respond, I could not confidently ask my question as I would if it were to be face-to-face. Sometimes, I asked a question, and due to network problems, I did not get an accurate response."*

Yaw responded,

> *"I could interact with lecturers sometimes, especially during live Zoom and Google Classroom sessions. I liked it because when we met on Google Classroom, I could ask questions, although infrequent."*

Kwame answered,

> *"Yes, sometimes I interacted with lecturers through Zoom Meetings and Moodle. Because of the many students, many of us could not communicate with our lecturers during live sessions. Some lecturers sometimes allowed course reps to ask questions or communicate, which affected me greatly since I dearly valued the interaction with my lecturers."*

The results show that Zoom, Google Classroom, and Moodle are platforms suitable for effective online mathematics learning. Also, from interviewees' submissions, it is seen that students interacted with their instructors on Zoom and Google Classroom and by posting questions on the Moodle forum, where lectures responded to them later. However, there were limited interactions with lecturers, especially during live sessions. Students were partially satisfied with the level of interaction they had with their lecturers, and they attributed their inability to interact with lecturers mainly to internet network challenges they encountered during online lessons, the large number of students in a live online class, and limited time with their lecturers during live sessions. Even though they could post questions for lecturers to answer later on the Moodle platform, they preferred on-the-spot questioning/ interaction during live lessons, thus suggesting a somewhat effective use of this strategy. From students' responses, it can be deduced that interaction as an instructional delivery strategy was somewhat effective as students could not interact frequently, especially during live sessions with their instructors, as they wanted.

The findings that Zoom, Google Classroom, and Moodle are platforms suitable for effective learning of mathematics online corroborate the findings of (Fatmahanik, 2021) that Google Classroom is a useful tool for teaching mathematics and can be used as a substitute for online instruction. However, it would be more effective if paired with other learning platforms and in-person instruction. The submissions indicating limited interactions with lecturers, especially during live sessions, also corroborate the findings of (Darius et al., 2021) that interactions by faculty during lectures were discovered to promote effective online learning.

When students were asked whether they could interact effectively with their classmates? (Probing for How examples), these were the students' responses:

Kwesi responded that,

> *"I interacted with my classmates through WhatsApp platforms. During the Covid-19 era, the lecturers gave many assignments: group and individual. Back then, the students formed WhatsApp groups where we discussed and worked on assignments on the platform. We submitted our solutions and discussed the final solutions on the WhatsApp platform. The group's secretary put them together and reposted them on the platform. When we had the final solution, the secretary submitted it to the lecturer."*

Esi's response was,

> *"Yes, I could interact with my colleagues. For instance, some lecturers put us in groups and gave us assignments. We worked together in our groups on our WhatsApp platforms, and when a group was ready to present the work, the group leader gave a thumbs up so that they could be called to present their work during a live session".*

Yaw said,

> *"We had a forum where questions were posted on Moodle for students to solve. Students discussed and uploaded solutions to questions posted.*

Kwame responded;

> *"Yes, I often communicated with classmates through phone and data calls. When I had difficulty with a topic, I discussed it with my mates through calls or WhatsApp."*

Based on the responses from the students interviewed, most agreed that they could interact effectively with their colleagues when learning mathematics online. Students interacted mainly through phone calls, chatting on the Moodle forum, and forming groups on WhatsApp, where they chatted and discussed assignments, solved questions, and learned concepts they could not understand. Students valued their interaction with their colleagues since they could learn together. From the findings, it can be concluded that students agreed that interaction with classmates as an online instructional delivery strategy was effectively utilized for learning mathematics online.

The findings concerning students' interaction with classmates corroborate previous findings (Baber, 2022) that social interaction has a considerably favorable impact on the effectiveness of online learning. As indicated above, the students were able to interact effectively through group discussion with their colleagues to understand concepts better, and this is in line with the assertion by (Rasmitadila et al., 2020) that by combining online approaches (group discussion), students were able to better their understanding of the subject. They responded well to online mathematics study. Again, the submission corroborates the assertion that forming a positive peer support network through social presence can give students the skills they need to navigate their private learning (Gedeborg, 2020). Again, the result of the study agrees with the finding of (Martin & Bolliger, 2018), who state that in the student-to-student category, icebreaker/introduction discussions and collaborative online communication tools were rated as the most helpful engagement strategies.

These were students' responses when they were asked whether they enjoyed studying mathematics through online mode (Probing for How/Why?).

Kwesi said,

> *"Not at all, because I did not get as many interactions with lecturers and classmates as I wanted."*

Esi answered,

> "*No, mathematics is a practical course where one-on-one interaction is the key. The system whereby I will be at a different place communicating online and the poor network in Ghana made it difficult to learn mathematics online, especially during live sessions. Sometimes, my network went off, and by the time I was back online, some concepts had been taught, and I experienced a conceptual gap. I could not interact smoothly with my lecturers as compared to my face-to-face lessons*."

Yaw, responded

> *"I did not enjoy learning mathematics in this mode due to our large numbers and limited time for online lessons, coupled with network challenges. Sometimes I want to ask a question, but I did not get the chance to do so"*.

Kwame said;

> *"I did not enjoy learning mathematics online because of network challenges. My network was usually poor, making it difficult for me to participate in lessons online. The high cost of data was also frustrating as I had to spend so much on data. I prefer face-to-face learning of mathematics to online learning of mathematics"*.

Generally, students' responses indicated that most of the instructional delivery strategies used by the lecturers were not effective enough to make them enjoy studying mathematics through online mode. Particularly, the student's perception of the effectiveness of their interaction with lecturers as an online instructional delivery strategy was low because of the challenges they went through in their online lessons. They attributed their displeasure mainly to their inability to interact enough with their instructors during live sessions. Also, limited time for lessons, the high cost of internet data, and bad internet networks prevented them from enjoying mathematics online. The finding on students'

inability to interact with their instructors corroborates previous studies, which found that the online instructional delivery strategy that most students perceived as not effective in their online learning was missing the interaction with lecturers (Alawamleh et al., 2020; Almarashdi & Jarrah, 2021).

The Second Research Question: What Challenges Inhibit Mathematics Students' Online Learning Effectiveness during the Covid-19 Era?

The research question sought to inquire about the challenges inhibiting the effectiveness of mathematics students' online learning during the COVID-19 era. In this instance, the challenges inhibiting the effectiveness of mathematics students' online learning rely on students' agreement/disagreement with the items on challenges students face. The result is presented below in Table 3 and the students' responses to interview questions.

Table 3. Challenges Inhibiting the Effectiveness of Mathematics Students' Online Learning during the Covid-19 Period

Items	SDf (%)	Df (%)	Uf (%)	Af (%)	Saf (%)	Mean	Std. Dev.
Online learning platforms used for lessons are easily accessible by phone.	22(6)	58(15)	70(19)	123(32)	106(28)	3.61	1.206
I can study (work) with my classmates during online lessons.	18(5)	41(11)	104(27)	139(37)	77(20)	3.57	1.075
The functions of online learning platforms are difficult to use.	26(7)	73(19)	75(20)	147(39)	58(15)	3.36	1.157
Student support services promptly addressed challenges students faced in online learning.	44(12)	80(21)	78(21)	100(26)	77(20)	3.23	1.306
I can confidently handle difficult tasks in the online learning mode	44(12)	69(18)	111(29)	105(28)	50(13)	3.13	1.200
I can communicate electronically with my instructors and classmates during online lessons.	26(7)	112(29)	82(22)	116(31)	43(11)	3.10	1.150
I have access to the Internet for my online lessons	49(13)	86(23)	102(27)	89(23)	53(14)	3.03	1.242
Overall Rating						**3.29**	**0.541**

Source: Field survey, 2022

Table 3 shows the descriptive statistics of the students' perception ratings of their agreement with statements describing some practices/activities that could be challenges they experienced in their online learning. From the table, it can be seen that the experiences that the students perceived (or rated) as least challenging were "Online learning platforms used for lessons are easily accessible by phone" (M = 3.61, SD = 1.206) and "There is an opportunity to study (work) with my classmates during online lessons" (M = 3.57, SD = 1.07). These are statements that about 60% of the students strongly agreed with, suggesting a substantial proportion (40%) of the students perceived the practices in these statements as those that could be challenges to their online mathematics learning.

Table 3 displays the topmost three practices/activities that could be challenging to online learning of mathematics experienced by the students. The proportion of students who agreed that it affected them is "I have access to the internet for my online lessons," with the majority 63% disagreeing with the statement; "I can confidently handle difficult tasks in the online learning mode" with the majority 59% disagreeing and "I can communicate electronically with my instructors and classmates during online lessons," with the majority 58% disagreeing with the statement. These, therefore, suggest the majority (about 60%) of the students perceived the practices in these statements as major challenges to their online mathematics learning. The overall mean and standard deviation of their challenges with online learning (M = 3.29, SG = 0.541) suggest the students agreed that they had challenges with online learning.

The finding on students' access to the Internet for online lessons confirms studies by researchers who found that students' negative reaction to online learning is because of the lack of regular Internet connectivity (Baticulon et al., 2021; Giray et al., 2022; Noori, 2021). However, the finding that about 57% of the students in the present study indicated they had the opportunity to study/work with peers or classmates during online lessons contradicts the observation (Almarashdi & Jarrah, 2021) that notably among students' opinions on challenges with online learning of mathematics is missing out on interactions with peers.

Interviews revealed challenges faced by mathematics students in online learning. They shared their difficulties and strategies to overcome them. Four students provided the following insights:

Kwesi responded,

> *"I had a lot of challenges with the Moodle platform when writing quizzes online because other students would be writing at the same time on Moodle, and the system became slow. Students who could not take part in quizzes due to network challenges could write them as supplementary papers conducted online later."*

Esi said,

> *"I am a visual student; I learn best when lessons are projected. However, in online learning, I only heard about it due to poor networks, and sometimes, when this happens, it becomes abstract for me, so I found it very difficult. However, with time, I learned to cope, and I found other means, such as watching videos on YouTube to catch up on missed sessions during online lessons."*

Kwame responded,

> *"Lecturers' notes were sometimes not enough to better understand concepts. Lecturers usually gave the salient points in the notes. When there were video lessons, lecturers compressed the video since students needed a lot of data to download. Thus, not much information was present. Also, sometimes, lecturers did not give enough examples for students to be exposed to various questions to help them understand the concepts. Hence, I downloaded videos on YouTube and watched them have more examples".*

Yaw stated,

> *"The cost of data was so high, and I had to visit the learning platforms frequently to attend lectures and access information; thus, spending all my money on data."*

From these submissions, it was deduced that the students sometimes had challenges understanding some concepts in online lessons, and they attributed this to lecturers compressing notes to reduce volume by giving few examples and salient points in notes. This means students had some challenges understanding course materials because they were not comprehensive enough. It also implies that students had difficulty understanding some concepts because they were not exposed to various examples in the learning materials. However, students usually consult colleagues or watch YouTube videos to understand the concepts better. Also, poor internet networks and the high cost of data were challenges that students faced in their online learning.

The observation that students had challenges understanding some concepts due to learning materials containing only salient points and few examples corroborates with the findings of (Alawamleh et al., 2020) that a lack of comprehension of learning material causes students to continue to prefer classroom instruction over online instruction. The findings of poor networks and the high cost of data being challenges that students faced in their online learning are in agreement with previous findings that having an examination online is difficult due to a bad internet connection and the expensive cost of internet data to access the Internet (Edem & Jibril, 2022; Reju & Jita, 2020; Wild & Schulze, 2020). Hence, poor internet networks and the high cost of data are major challenges that students face in their online learning.

LIMITATIONS

The generalization of this study's findings contains a limitation because the sample population was drawn from a single public university. Therefore, the result may not apply to undergraduate mathematics education students at all universities in Ghana. Third-year students for the 2021/2022 academic year were employed in the study because the third-year students had experienced face-to-face, fully online, and hybrid modes of learning mathematics and could speak to the issue well. Again, the researchers believe that lecturers' voices were also crucial in this issue.

CONCLUSION AND SUGGESTIONS

Students' perception of the effectiveness of online instructional delivery strategies is key to successful online mathematics learning. Therefore, educators and institutions should ensure its success. To encourage students to enroll in online mathematics programs, challenges encountered by mathematics students need to be addressed. The findings are important for the development of enhanced online mathematics programs.

Since the overall mean rating on instructional delivery strategies seems to suggest the students marginally agreed that the delivery strategies were effective, it is recommended that lecturers be continuously trained on effective strategies for online instructional delivery to enhance online mathematics programs. The discussions show that students want to interact more with their lecturers in online lessons. Hence, lecturers should schedule more time for interaction with students. Students should read recommended materials and other useful materials they may find to have a broader knowledge of concepts and be exposed to a variety of examples for a better understanding of concepts. The University should make its online learning platform accessible to students without data so that students would not be burdened with the data access problem and the high data cost for their online studies.

AUTHOR CONTRIBUTIONS

LAL conceptualized the research framework, conducted data collection and analysis, and contributed to drafting the manuscript. COA reviewed the research design, provided critical revisions to the manuscript, and assisted in interpreting the data.

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