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Research Article

Online Mathematics Learning Experiences of Students During the COVID-19 Pandemic: Basis for Developing a Post-Pandemic Online Learning Environment Model

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ABSTRACT

The forceful and sudden shift to fully online learning brought about by the COVID-19 pandemic disrupted the normal teaching and learning process in higher education institutions. Through a qualitative descriptive approach, this study aimed to (i) describe the experiences of students in online mathematics learning, (ii) from the experiences, characterize through themes the students' perspectives on effective online mathematics learning environment, and (3) use the themes as bases in proposing a model for online mathematics learning environment. The study's participants were students of a higher education institution in Lipa City, Philippines, in the second-year to fourth-year level, enrolled in the school year 2022-2023, and had experienced full online mathematics learning during 2020-2021 and 2021-2022. Data were gathered in two phases using SWOT analysis and then focus group discussion. The analysis of data involved thematic analysis through text analytics software. Results showed that the students' online mathematics learning experiences were related to the following areas: (i) learning support of the school, (ii) communication and information dissemination, (iii) feedback on assessments and activities, (iv) studying and preparing for course requirements, (v) change in one's self brought about by online learning, and (vi) digital literacy among teachers and students. Based on the thematic categorization of student experiences, findings revealed that social presence, enriched online synchronous class, effective communication, and enhanced feedback mechanism compose an effective online mathematics environment. A model for an online mathematics learning environment was proposed to provide a useful lens to illustrate the relationships among these four components. This work adds to the information regarding mathematics online learning during the COVID-19 pandemic. The results of this study offer a standpoint in the Philippine context where teachers of higher education institutions should focus on designing.

INTRODUCTION

The global spread of the coronavirus disease 2019 (COVID-19) in 2020 marked a major transition in Philippine educational institutions. In compliance with the government's quarantine protocols, schools had to be temporarily shut down, affecting over 28 million Filipino students at all academic levels (Unesco, 2020). Even then, both the Department of Education and the Commission on Higher Education released a directive that learning should continue despite the pandemic (Department of Education, 2020) through the deployment of alternative learning platforms in place of the required contact hours for a course or a program, (Commission on Higher Education, 2020). From a predominantly face-to-face mode of instruction, higher educational institutions shifted to a full online mode of delivery, causing a direct impact on

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students, educators, and institutions (Chandra, 2020) and the teaching-learning process (Dubey & Pandey, 2020; Onyema et al., 2020).

According to Ray (2020), remote learning allows students and teachers to stay connected and engaged while working from their homes. While the effect is generally on all forms of learning, learning mathematics is particularly challenging due to its complexity and abstract difficulty. In the context of online mathematics, the forceful yet important shift towards online learning brought about challenges not only among teachers (Radmehr & Goodchild, 2021; Radmehr & Goodchild, 2022; Tanujaya et al., 2021) but with college students as well (Calder et al., 2021; Casinillo et al., 2022; Gocotano et al., 2021; Mendoza et al., 2021; Mina et al., 2020; Mukuka et al., 2021; Wardani et al., 2021).

The study explored how an effective online mathematics learning environment can be designed based on the experiences of college students in their mathematics classes during the COVID-19 pandemic. It also probed their outlooks on what promotes an effective online mathematics learning experience were probed.

For many years, even before the pandemic started, online mathematics teaching and learning have received considerable attention in mathematics education research. For online mathematics, some studies investigated the integration or assessment of technology as an instructional aid in the online mode of teaching mathematics (Alomari, 2009; Kalbani et al., 2020; Karal et al., 2015; Mestel et al., 2011; Moradi et al., 2018; Msomi & Bansilal, 2018; Namukasa & Ganadinis, 2011; Petty & Farinde, 2013). Specifically for online mathematics learning, studies involving students' learning experiences (Boling et al., 2012; Reju, 2016; Msomi & Bansilal, 2018; Reju & Jita, 2018; Thompson & McDowell, 2019), perspectives (Adnan & Boz, 2015) of teachers and students, comparison of students' learning and other success outcomes in online, blended, and face-to-face instruction (Thompson & McDowell, 2019; Trenholm & Peschke, 2020), and student satisfaction (Davis, 2014; Glass & Sue, 2008; Thompson & McDowell, 2019) can be found in the existing literature.

The shift towards online education during the COVID-19 pandemic has resulted in studies focusing on several areas in the teaching-learning environment, mainly the experiences (Calder et al., 2021; Mukuka et al., 2021; Radmehr & Goodchild, 2021; Radmehr & Goodchild, 2022; Taley et al., 2021) and challenges encountered (Tanujaya et al., 2021; Wardani et al., 2021) by the students. Associated with these are the studies that dealt with student perception and satisfaction in online mathematics learning brought about by the shift in modality (Baber, 2020; Gopal et al., 2021; Laksana, 2020). Other studies, on the other hand, focused on other aspects such as assessment of learning (Kamsurya, 2020; Pocsova et al., 2021), online learning effectiveness (Fajri et al., 2021; Ilmadi et al., 2020), students' mathematics self-concept, mathematics anxiety, mathematics learning independence (Delima & Cahyawati, 2021), cognitive engagement (Hidayah et al., 2021), and even academic success (AbdelSalam et al., 2021).

Correspondingly, there have been studies on

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teachers' various strategies in an online learning environment. Literature reveals that as early as pre-pandemic, teaching in the e-learning environment or platform had been explored (e.g., Brancaccio et al., 2015; Karal et al., 2015; Moradi et al., 2018;). The research trend continued during the pandemic in which, by and large, the focus of the strategies became didactic based on the situation that necessitated full online teaching (Capone & Lepore, 2021; Daher et al., 2022; Marfuah et al., 2022; Zabala-Vargas et al., 2021).

In the Philippines, there are studies in recent literature that delved into the experiences (e.g., Nabayra, 2022) of students in online mathematics learning. Mainly, the attention is on the challenges faced by the students (Bringula et al., 2021; Casinillo et al., 2022; Gabales et al., 2022; Gocotano et al., 2021; Mina et al., 2020). However, little research can be found on the perspectives of students on effective online mathematics learning environments as shaped and influenced by their own positive and negative experiences, especially in the Philippines. The question "What promotes effective learning experiences in an online mathematics class, and what teaching model can be recommended based on them?" remains, hence the need for added research.

This study's main objective was to explore students' experiences of students in their online mathematics classes during the COVID-19 pandemic. Specifically, it aimed to (1) describe the experiences of students in online mathematics learning, (2) from the experiences, characterize through themes the students' perspectives on effective online mathematics learning environment, and (3) use the themes as bases in proposing a model for online mathematics learning environment.

In this study, mathematics learning pertained to those courses at the college level and did not include those in the primary and secondary levels. While online mathematics learning existed even before the COVID-19 pandemic began, this paper centered on the experiences of the students brought about by the transition from a predominantly face-to-face mode of learning to a fully online setup, specifically during the school years 2020-2021 and 2021-2022.

MATERIALS AND METHODS

The study was conducted at a higher education institution (HEI) in Lipa City, located in the northern part of the Philippines, Luzon. A qualitative descriptive approach was used to probe the students' experiences in online mathematics learning. Two phases of data gathering were completed. The preliminary is the strengths, weaknesses, opportunities, and threats (SWOT) analysis, while the principal data collection is through a focus group discussion (FGD).

The SWOT analysis is an effective framework for analyzing the strengths, weaknesses, opportunities, and threats of a project to address the effectiveness of its planning and implementation (Sabbaghi & Vaidyanathan, 2004). Primarily, the framework attempts to reveal the strengths and weaknesses to analyze opportunities for improvement and to see possible obstacles that should be anticipated (Thamrin & Pamungkas, 2017) for informed strategic planning and decision-making. According to Pickton and Wright (1998), SWOT analysis has been praised for

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its simplicity and practicality. As a framework, it has been widely adopted. It has the potential to become a significant tool in identifying the factors most likely to influence a project's strategy and success. Although it was originally developed as a business tool to aid decision-making, there are existing studies that used SWOT in analyzing strategies in higher education (Longhurst et al., 2020; Romero-Gutierrez et al., 2015; Thamrin & Pamungkas, 2017) and medical education (Burr, 2009; Dixit & Marahatta, 2008; Leiber et al., 2018; Liu, 2017; Sharma, 2005). Further, the approach is used to initiate meaningful change, designed for decision-making, and as a precursor to strategic planning (Romero-Gutierrez et al., 2015).

The FGD, on the other hand, is a method where a researcher brings together a group of individuals to discuss a specific topic targeting to draw beliefs, perceptions, and attitudes of the participants from their personal experiences through a moderated interaction (Cornwall & Jewkes, 1995; Hayward et al., 2004; Israel et al.,1998; Kitzinger, 1994; Morgan, 1996 as cited in Nyumba et al., 2017). It is frequently used to gain an in-depth understanding of social issues to acquire data from a purposely selected group of individuals instead of from a statistically determined sample of a broader population (Nyumba et al., 2017).

2.1 Participants

For the SWOT analysis, 16 participants took part in this study. While the focus of this study is on student experiences, to gather a wider range of perspectives, aside from students, other stakeholders such as teachers, school administrators, and parents were included as participants. The SWOT analysis participants comprised six students, six teachers, two school administrators, and two parents. There were eight student participants in the FGD. The participants were purposely selected based on the following criteria for students: (a) in the second-year to fourth-year college level, enrolled in the HEI during the second semester of the school year 2022-2023, and (b) have consistently taken mathematics courses in the HEI from SY 2020-2021 to SY 2021-2022; and for other stakeholders, (c) have been connected with the HEI during the school years mentioned above.

2.2 Data Collection

The first phase delved into the strengths, weaknesses, opportunities, and threats of the online learning modality as substantiated by the students' experiences. The guide question was, "In terms of the strengths, weaknesses, threats, and opportunities, how would you describe online mathematics learning experiences of students during the COVID-19 pandemic, specifically during the school years 2020-2021 and 2021-2022?" The responses gathered were coded, grouped, and afterward underwent a thematic analysis to elicit the essence of the participants' experiences (Morse, 2008, as cited in Vaismoradi et al., 2016).

A set of questions was outlined using the emerging themes before the next phase, the FGD. Experts were invited to review, refine, and validate the questions based on the gathered themes to ensure their alignment with the study's objectives.

A facilitator conducted the FGD face-to-face in

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July 2023 at the HEI campus. Before the FGD proper, the participants were properly briefed. The background and purpose of the study explained in the consent letter previously disseminated to the students were reiterated, as well as their voluntary participation. It was made clear that any information that will be gathered, containing sensitive information, will be used solely for the study.

Through the FGD, the experiences and insights of the students were explored. The session was guided by the following questions based on the preliminary data gathered from the SWOT analysis.

1. In what ways has the school assisted you in learning during the pandemic?
2. Describe the nature of communication (and collaboration) between you and your teachers and the information dissemination when mathematics learning was online.
3. What can you say about the feedback mechanism on activities and assessments at that time?
4. How has studying and preparing for your course requirements changed for you during the pure online modality, compared to how you did before the pandemic?
5. How has online learning changed you as a student?
6. What can you say about digital literacy among teachers and students when mathematics teaching and learning are accomplished online?
7. What were your biggest issues and challenges in taking an online mathematics class?
8. Based on your experience, what could have been done more (or better) in the online learning setup that you think have contributed to a better experience for you as a student?

2.3 Data Analysis

The data from the FGD were analyzed using IBM SPSS Text Analytics Software for thematic analysis. The software created codes and categorizations of responses. While the unstructured qualitative data are transformed into a synthesized form that facilitates more efficient, comprehensive, and transparent data familiarization and coding, the method still requires researcher-led interpretative analysis for meaningful results (Haynes et al., 2018).

From the computerized transcriptions of responses from the FGD, the software processed the transcribed word-for-word responses by identifying the frequencies of similar words from various statements and then building categories or themes. It sorted out the data by taking note of similar words from the responses and then tagging them as 'extractions.' These extracted words are where the categories and themes are built upon. Also, the statements and participants involved in the generated themes were identified.

A set of emerging themes was identified for each FGD question. Then, across all the themes generated from all eight questions in the FGD, a thematic categorization analysis was done to extract the overarching concepts that surfaced in the study. The relationships among the concepts were illustrated through a model that underwent expert validation.

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2.4 Ethical Statement

All participants in this study were invited with ethical considerations. Through a formal letter, their permission and consent to participate were sought before starting both data collections. It was made clear that their participation in the SWOT analysis or FGD is completely voluntary and that they can withdraw anytime they wish not to continue. The privacy and confidentiality of the responses and the anonymity of the participants were assured. Likewise, the data are saved with password protection and stored in a secured cloud. After two years, it will be deleted.

This research also underwent review by an ethics committee to ensure compliance with all relevant school policies and regulations governing research involving human participants.

RESULTS AND DISCUSSION

The data gathered revealed the views and insights of the participants on what promotes an effective online mathematics learning environment based on their experiences during the COVID-19 pandemic. The results of the thematic analysis are presented and discussed following the first two principal objectives of the study: to (1) describe the experiences of students in online mathematics learning and, (2) based on the experiences, characterize through themes the students' perspectives on effective online mathematics learning environment. The last part presents a proposed model for an online mathematics learning environment based on the results gathered.

3.1 Experiences in Online Mathematics Learning

A. Learning Support of the School

In the first question, three themes emerged when the students were asked how the school had assisted them in learning during the pandemic. First, all except one of the participants thought that the online synchronous sessions were helpful in their online learning. Virtual Class Engagement (VCE) is a synchronous class that is conducted at least every week for each subject, depending on its credit hours. According to Student 1, the school assisted them in learning "by providing constant guidance, especially since the set-up is virtual." Similarly, Student 4 stated, "The school assisted us in learning mathematical concepts through the conduct of VCEs by the teachers. During VCEs, solving problems and discussing theoretical concepts were carried out." The remark was related to the response made by Student 3, saying, "The teachers were able to explain the lessons in a clear manner, which was accompanied by supplementary exercises, visual aids, and other examples." Lastly, Student 2 gave a profound insight, narrating, "I think the school assisted us in learning during the pandemic through detailed discussions where our professors would share-screen the modules in Canvas (the HEI's learning management system). Then they would discuss the details there and teach us how to solve the mathematics problem step-by-step." The sharings of the respondents were indicative of the continuity of students' learning through the teacher-student interaction in synchronous sessions, which, in the context of this study, was done via VCEs. This finding is consistent with those reported by other researchers who established continuity of learning through online engagement between the teacher and students. For one, the result of the

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study by AbdelSalam et al. (2021) suggested that if the synchronous mode is used for instruction and if an experienced educator delivers it in a student-centered manner, the damages brought about by the pandemic might not be as widespread as it seemed to be. Thus, online synchronous sessions promote active learning, making online learning a sustainable option (Stevens et al., 2021). Also, according to Sahin and Shelley (2020), students had a positive experience with online learning and felt confident about it from the interaction it brings about. While students acknowledge the need to put more effort into their learning, the online modality is still perceived as flexible, useful, and helpful. Generally, students recognize online classes as effective in ensuring continuity of learning during the pandemic (Delicano, 2020).

Another idea that surfaced in the responses to the first question is providing online class (VCE) recordings. In the HEI involved in this study, teachers were required to record all VCEs and save them in an online repository for the students' access. Student 5 shared, "I think the school assisted me in my learning during the pandemic through the recorded videos of VCEs and the supplementary videos since we can review the lecture and go back to the concepts we are struggling with or have forgotten to master on how to solve." Student 7 agreed with the statement and further added that she used "to play back recordings to practice the sample problems that were given earlier by the teacher." Further, as said by Student 6, "because it can be difficult to understand a mathematics concept just by listening to the teacher, a video reference that you can play back is helpful." The VCE recordings, according to Student 8, are "of significant assistance provided by the school to those who could not attend the class due to barriers or issues encountered." From these responses, it can be gathered that the students perceived the provision of VCE recordings as an important aid the school had given them in their online mathematics learning. This result is in line with the study of Nabayra (2022), who found that videos, which, in the context of the study, are the VCE recordings, are beneficial to the students in that they make mathematics learning flexible in terms of time and place. These videos represent the multimedia and modality principles of Mayer et al. (2015), which state that using any two out of the combination of audio, visuals, and text promotes deeper learning than using just one or all three. Further, with the accessibility of the videos on the students' phones, they become more effective in that the students can watch them anywhere, anytime (Kahrmann, 2016), which affirms the Learner Control Principle that states that learning is more effective when the learners can control the rate at which they learn (Mayer et al., 2015).

The third and last theme that emerged in line with the learning support for students provided by the school is the teacher's presence. While learning was online and discussions were virtual, the students noted other forms of teacher assistance besides VCE recordings. For one, the teachers "supplied the students with YouTube videos where they could get additional information on how to solve problems easily" (Student 2, Student 6). Also, there were "supplementary exercises, visual aids, and other examples provided" (Student 3) aside from "e-book recommendations that the students used in mastering their subjects even better" (Student 7). While many of the responses are linked to

assistance with academic needs, it is worth noting that Student 4 mentioned that "the school assisted them by opening their lines whenever they (the students) need advice on their problems." Relating this to the study of Boling et al. (2012), the results reflect how students in an online learning environment can be affected by their social learning environment and that teachers must design an environment that supports student learning and motivation. Further, simple actions by teachers, ensuring lines of communication remain open, can be very effective in students' online mathematics learning (Radmehr & Goodchild, 2021). The interaction between teacher and students, thus, is an important determinant of student-perceived learning and satisfaction (Baber, 2020).

B. Communication and Information Dissemination

When the students were asked to describe the nature of communication and collaboration between them and their teachers, as well as the information dissemination at that time when mathematics learning was online, three points floated during the focus group discussion, the first of which is the various means of communication that were done "directly or indirectly" (Student 4). Most participants noted the different lines of communication used at the time, namely, Canvas Announcement, Canvas Inbox, Gmail, FB Messenger—private messaging and group chats, and Zoom. In the FB Messenger group chat, Student 2 reported that they "were encouraged to send their questions there so that all inquiries and answers to them will be centralized there," further adding that "it was easier for them to read announcements through the FB Messenger since students were more active in it." There was also flexibility noted on the part of the teachers as Student 3 recalled that their teachers "allowed the students to communicate with them through FB Messenger or Canvas Inbox during class," In summary, the various online platforms were perceived as helpful by the students when it comes to communication and information dissemination. Studies show that online learning is implemented well when technological developments such as smartphones, tablets, and laptops are utilized to access information anywhere and anytime (Gikas & Grant, 2013; Hermanto & Srimulyani, 2021). Also, as Cao et al. (2021) suggested, technology needs to be expanded during classroom instruction, reshaping how teachers interact with students. The researchers also posed that integrating technology with instructional practice is a critical role of teachers in online learning that determines effective online teaching.

Corresponding to the different means of online communication presented, the second point to emerge in the FGD was the perceived open lines of communication between the teachers and students. As said by Student 1, whenever they have VCE, "the teachers were approachable enough to ask always if they have questions or clarifications." This was supported by Student 2, who felt that they could "at any time raise their concerns and ask questions about matters they needed clarification on." It is also interesting to note what Student 6 shared: they were "allowed to contact their teachers anytime during the day," indicating open communication between teachers and students. Student 8 validated this by saying, "We did not need to set a schedule. We were told just to send a message, then they (teachers) will respond as long as they are

available." In the study of Desai et al. (2009), "two-way interaction is a critical feature of the education process" (p. 328). This is why one of the greatest challenges learning institutions face when implementing and designing online courses is providing a sense of community and open communication. This resonates with the study of Harunasari et al. (2021), revealing that students agreed that modes of communication, whether private or during online learning, supported their need to grasp the meaning of content and information. For distance education to be successful, Desai et al. (2009) claimed that high levels of interaction should be present for learners to have a positive attitude and greater satisfaction. This should be matched with teachers' guidance and interaction with them. Given that there is no physical setting, the researchers believed this plays a significant role in establishing a sense of community in an online learning environment.

The remaining point was the effectiveness of communication and information dissemination. Each participant gave his/her assessment, which, all in all, varied with the following breakdown: 2–effective, 1–mostly effective, 2–somehow effective, 2–slightly effective, and 1–effective. Student 1 thought "information dissemination was effective as it was done through the school's learning management system (Canvas)." This was affirmed by Student 5, saying that "when it comes to reminders and announcements, the dissemination was effective as they can be posted in Canvas." She added that "information was clearer and effectively reminded the students of what requirements were to be passed." Student 4 followed it up by saying, "Since there were details and other information that students tend to forget, it is good that there was a Canvas Announcement page that we could always check." It can be gleaned from these responses that for communication to be effective, teachers play a vital role in moderating the online platforms mainly used by the participants (Watts, 2016). Through online teaching, teachers solve the mismatch between online learning and mathematics by putting together various online tools and resources (Smith et al., 2008).

On a different note, concerning the assessment that communication and information could be more effective, an idea is in connection with a comparison between a face-to-face teaching-learning environment and an online setup. As cited by Student 3, "Considering the nature of mathematics as a subject, concepts were explained properly and were understood better when done face-to-face." Although the teachers were very responsive, the full information needed by the students could not be given." The last insight aligns with a study by Hill et al. (2009), who found that one major complaint about computer-mediated communication is the lack of social cues. In online mathematics, teachers and students need help communicating with mathematics notation (Smith et al., 2008), posing a challenge in the learning setup.

C. Feedback on Activities and Assessments

Concerning feedback on checked activities and assessments, generally, the students expressed dissatisfaction. Two themes became evident in the responses of the students. First, there needed to be more opportunities to verify wrong answers. While they received their graded assessments, it concerned them that most

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of the time, they did not have a way of knowing why the wrong answers were marked as such. As narrated by Student 2, "All that we could see were the numerical scores, and there were no comments on where or why our answers were wrong." Student 3 had the same response adding that "it was not explained how her solutions were wrong." It was pointed out, however, that "some teachers tackled the wrong answers, but there are only a few of them" (Student 7). It was thus "difficult for the students to fully comprehend which part they were wrong at" (Student 4). To address it, Student 6 shared that "sometimes they would consult other students from higher year levels or go online like on YouTube" to get the needed answers. These results show that while technology was adopted in giving assessment feedback, the teachers failed to provide the students with what they needed besides the test scores. Grades, according to Rakoczy et al. (2013), provide little information about the actual performance and the learning goal. Rather, "the chance of learning from mistakes turns assessment into a fundamental enhancement in education" (Barana & Marchisio, 2016, p.1).

The other theme that emerged in the context of feedback on activities and assessment is delayed feedback. As meetings were once a week per subject, Student 1 recounted that "they had to wait for another week for when the assessments will be checked." This was backed up by Student 6 saying, "Whenever we need to contact them (the teachers), they cannot immediately give feedback on assessments, so we had to wait for a week because they only discuss the correct answers during VCEs." Also consistent with this was the sharing of Student 2: "When we tried to ask where and why we got the wrong answer, we could not get an immediate response." As added by Student 3, "It took time before feedback was given." Studies show prompt feedback influences student satisfaction (e.g., Gopal et al., 2021). Correspondingly, Sabtiawan et al. (2019) reported that opportunity for discussion and teacher feedback positively impacts students' learning attitudes and performance. Learners think teacher feedback will improve their understanding and work quality. Aside from that, prompt feedback enhances the learning experience of the students (Brownlee et al., 2009), and it has also been found to boost satisfaction among them (O'donovan, 2017). It is a self-evaluation tool for students (Rogers, 1992) by which they can improve their performance (Gopal et al., 2021).

D. Studying Before and During the Pandemic

In describing how studying and preparing for their coursework changed before and during the pandemic, the students' responses converged into one theme: the traditional (face-to-face) setup preference. Two reasons became apparent in the statements given, the first of which is that they felt more motivated by the traditional way of learning. According to Student 3, "During face-to-face learning, students were more driven, especially in trying to answer exercises during recitations." He added, "In the online modality, it was not as challenging as you cannot give your hundred percent thinking that it is okay to be passive. In the traditional setup, you had to exert efforts to participate." Student 5 had the same thought to share, saying that she "preferred the traditional setup because of the attention and commitment to studying" present on her part and that they (students) "can absorb more

learnings there." This was also aligned with how Student 6 felt, sharing that "back in the traditional setup, she was motivated to listen as there was a real-time exchange of ideas." She also emphasized how she struggled in the online setup because of her internet connection. She recalled, "I had to adjust and wake up at 4:00 in the morning to open Canvas (the learning management system) as the connection is only fast during dawn." The preceding statements show how many factors influenced the students' preference for the traditional setup over the online modality. A study by Bringula et al. (2021) found that a student's ability to learn and study online poses difficulties and barriers that hinder the effective implementation of online learning. Moreover, because social presence—open communication and group cohesion is absent in online mathematics learning environments (Garrison, 2011), weak social-emotional experiences among the students could arise (Taley et al., 2021). With the concern raised on internet connectivity, research confirms that internet connection alongside power interruption was the most problematic aspect of online learning (Bringula et al. (2021) and that challenges faced by the unavailability of a network, economic instability, digital divide, the shortage of digital devices, distractive learning environment, expensive internet data, health-related problems, lack of resources, lack of digital literacy skills, and loss of motivation (Gocotano et al., 2021; Hermanto & Srimulyani, 2021; Wardani et al., 2021).

Further to why face-to-face learning was preferred, the other idea solicited from the respondents was the importance of teachers' presence. Student 7 firmly said that she "preferred hearing the teachers face-to-face." She further stated that she prefers "solving while the teacher is present (physically) so she can readily consult the teacher about a math problem." Students 6 and 2's responses supported this: they "could immediately ask the teachers if they (students) have questions or concerns." In an online class, as cited by Student 1, "When you fail to understand something, you will resort to watching videos on YouTube or wait for a week for the next meeting." Student 2 remembered feeling "shy to ask or interrupt during online discussions," something that would not have been the case if it were in the traditional setup. She also emphasized the "importance of teachers' physical presence and guidance as they practice the strategies taught, especially when they solve on the board." Linking these responses with existing studies, in the study of Mukuka et al. (2021), students believe that mathematics is a subject that is best learned through face-to-face interactions between the teacher and students and among students. In online learning during the pandemic, students missed social contact and being physically present at their school (Radmehr & Goodchild, 2021). The lack of physical collaboration and human interaction resulted in dissatisfaction and frustration among students in a learning environment, such as no direct interaction with other students to clarify and mediate their thinking (Calder et al., 2021). Interestingly, this reflects the result of a pre-pandemic study revealing that while students acknowledged the contribution of the e-learning platform, they were still unsatisfied with the learning provided because of the low student-student and student-teacher interactions (Alomari, 2009).

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E. Change in One's Self Brought About by Online Learning

On the fifth question, "How has online learning changed you as a student?" two themes emerged in the responses given by the students. First, many believe that online learning has transformed them to become more resourceful. Student 3 said, "Since it was pandemic, our resources were very limited, so I had to find ways. In that way, I became more resourceful in acquiring my needs." Student 6 shared the same insight mentioning that "online learning pushed her to adapt to changes, teaching her to become resourceful. And like Student 3, she "had to find ways to learn particular topics and lessons on her own." Further, as cited by Student 7, she "discovered many skills during online learning, one of which is resourcefulness." Overall, the responses emphasized how resourcefulness was even more developed in online learning during the pandemic. This affirms the study of Ulla and Perales (2021) on student experiences in online learning classes, where it was found that learners became more independent, responsible, creative, and resourceful when immersed in online activities, individually or collaboratively. As Harunasari et al. (2021) argued, the setup influenced students' engagement in the learning environment, making them resourceful. The researchers also uncovered that adapting to a new learning perspective allowed the students to be resourceful in applying their knowledge to solve problems.

Aside from being resourceful, the students thought online learning developed their time management skills. As shared by Student 4, "I learned how to manage my time because it was during the pandemic when I learned what tasks to do and prioritize at a given time." This was supported by the responses of Student 1 and Student 8, who both claimed that "online learning improved how they manage their time to use it more efficiently." Similarly, Student 5 remarked, "As a student leader, even during the pandemic, I could multitask and balance my time for all the tasks I need to finish." The students were disciplined to manage their time independently as they adjusted to the learning environment. Studies about online learning during the pandemic show how time management contributed to students' learning outcomes. For one, the study of Ilhamdaniah and Megayanti (2020) highlighted the significant impact time management has on online learning outcomes. In a parallel work by Khalil et al. (2020), time management was one of the core themes in the participants' perceived effectiveness of online learning, who agreed that their performance was improved due to enhanced time utilization. Meanwhile, a study by Barrot et al. (2021) about how students in the Philippines cope with the pandemic's learning challenges revealed that time management is one of the most frequently used strategies employed by students along with help-seeking, technical aptitude enhancement, and learning environment control.

F. Digital Literacy Among Teachers and Students

When asked about digital literacy among teachers and students during online learning, the participants said it developed over time. They all saw the transition, especially of teachers, from needing to become more acquainted with the various technology platforms to someone who can easily navigate them

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during online classes. Student 4 recalled, "The teachers' digital literacy was developed as time passed. At first, we could not start a class immediately as the teacher was still trying to figure out how to begin a presentation." Additionally, "some were not used to Google Meet, Zoom, and the like" (Student 2, Student 5, and Student 7). However, "along the way, the teachers and students have improved and enhanced their technological skills" (Student 6). From the point of view of Student 2, the pandemic became a "learning curve for both teachers and students as they got more used in utilizing different tools like breakout rooms and Whiteboard." She said, "For us students, we also had discoveries and explored websites where we could get resources that could help us solve math problems." Similarly, the students "became more proficient" (Student 3), and the experience "helped them to discover and learn much software that can be used in studying" (Student 1). On the part of the teachers, Student 3 recounted, "Eventually, we saw our teachers using Whiteboard on Zoom to solve problems, and we could say that their digital literacy was enhanced." Essentially, the responses gathered reveal that digital literacy stemmed from the pressing need for teaching and learning to continue during the pandemic and was later acquired by teachers and students. This relates to existing studies in the literature, such as Barrot et al. (2021), who claimed that teachers, who were used to conventional teaching delivery, were obliged to embrace technology despite their lack of technological literacy. In a study by Radmehr and Goodchild (2021), teachers shared that because of their limited use of technology in teaching before the pandemic, it took time for them to learn how to work with online platforms for teaching. Also, some needed to familiarize themselves with online platforms to communicate between students and teachers. On the other hand, Gabales et al. (2022) emphasized how students' level of digital literacy is correlated to their mathematical performance. They argued that in online mathematics learning, students should be well-versed in the e-learning system to accomplish their learning task, manifested in their digital literacy skills.

G. Issues and Challenges

Of the issues and challenges the students face in online mathematics classes, three emerged as majors. First is the communication barriers in the online setup. Five participants shared that they needed help to raise questions or clarifications during online classes. Students 2, Student 6, and Student 8 said it was "tough for them to interrupt the teacher during a discussion to raise questions, clarifications, or concerns." Also, as Student 3 mentioned, "If she found a certain part of the lecture unclear, she could not immediately consult the teacher about it." While she sometimes found a way to understand the lecture, she still believed that "it is still different when the teacher discusses the topic in the simplest way possible." Student 4 shared, "When in Google Meet, I tended to get shy about asking a question even if the teachers encouraged us to ask questions after the discussion." It can be deduced from the student responses that even if there is a virtual interaction between them and their teachers, it was difficult for them to communicate their thoughts to their teachers, especially their questions in the lectures. This finding is consistent with what Adnan and Boz (2015) found out that the lack of interaction between teacher and students is considered the most important

challenge in online learning, "particularly for those participants with no prior online experience" (p.32), like the students involved in this study. Accordingly, in the study of Boling et al. (2012), students thought that connecting to their instructors was difficult. The statements shared by the participants validate how social interaction plays a role in students' sense of learning community (Hill et al., 2009). Students want live communication (Radmehr & Goodchild, 2021). In an online class, the students' accessibility to instructors and information is fundamental and a determinant of their overall impressions of their learning (Boling et al., 2012).

Another challenge experienced by the students is understanding mathematics lessons and concepts in an online learning environment. As imparted by Student 1, she "struggled to absorb the lessons immediately and had to study them again to understand them." Related to this, when it comes to studying the modules in the LMS, Student 4 said that "it was a challenge for her to learn mathematics concepts by herself because of the nature of the subject, not to mention the distractions at home that affect her attention span and engagement." Student 7 felt that overall, "the quality of learning declined as no matter how serious they (students) were in fully understanding the lessons, they still failed to comprehend." The statements disclose how difficult it was for the students to understand the concepts and lessons in their online mathematics class. This agrees with the findings of Casinillo et al. (2022) that due to anxiety brought on by the pandemic and the distractions surrounding the students, they could not focus on their mathematical activities. Additionally, due to limitations and barriers in remote learning, students need help understanding their lessons, one reason for which is the less interaction and proper guidance from teachers. The absence of helpful and visible teachers (Reju & Jita, 2018), along with the digital connection and time-limited submission of assignments (Mendoza et al., 2021), posed the challenge of understanding mathematics among students.

The last issue on mathematics online learning that surfaced in the students' responses is internet connectivity. Student 8 recalled that the internet connection of both teachers and students was not always stable. As narrated by Student 5, "The biggest cause that affected our learning in online classes is the quality of the internet. No matter how resourceful students are, when the resources are limited, they are hindered from maximizing their learning." This was concurred by Student 6, adding that "no matter how eager students are to learn a particular topic, if there is hindrance like the internet connection, it will be difficult for them to grasp the lesson they want to learn fully." A wide range of studies conducted during the pandemic showed that internet connectivity is one of the most problematic aspects of online learning (e.g., Barrot et al., 2021; Bringula et al., 2021; Mina et al., 2020; Mukuka et al., 2021; Ulla & Perales, 2021). According to Radmehr and Goodchild (2022), advanced technology and the internet were only partially successful in supporting many students and teachers in their adjustment to the online learning environment. At least in the context of teaching and learning mathematics, neither of the two could replace the experience students have in face-to-face teaching and collaborative learning environments at the schools.

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H. Student Recommendations

When asked what could have been done better to improve the students' online learning experiences, the responses leaned towards two themes: enriched synchronous class and enhanced feedback mechanism. About the conduct of online synchronous class, for Student 2, "there could have been more time allotted for the students to be the ones to answer and discuss the problems themselves, instead of the teacher doing almost all the discussions." She adds, "That way, the understanding and skills of the students could be enhanced with the constant practice exercises." This aligned with the response given by Student 5, who said that it would have been better if "it was like in the face-to-face setup where the discussions were interactive between the teacher and students." She emphasized, "What is missing in an online class is more opportunity to be called to solve impromptu, like how it is done in a face-to-face class." Similarly, Student 6 thought "an increased attempt by the teachers to draw active participation from among them (students) could have led to an improved student engagement during an online class." Although not directly relating to student-teacher active engagement, the insight shared by Student 3 also touched on student participation, but through collaboration with other students. He stated, "There could have been some activities or times wherein the students would collaborate with other students to discuss math problems. If, for example, a student could not grasp information the way the teacher explained it, he or she might understand it from another student's explanation." The opinions shared by the respondents establish the students' perceived need to be more engaged, both with their teacher and classmates, rather than listen to or watch their teachers discuss the math problems in their online classes. A study by Boling et al. (2012) underscored that the presence of social exchanges is one of students' favorite aspects of their online courses. As a study by Harunasari et al. (2021) revealed, peer collaboration was the most engaging factor in sustaining students' engagement. Interactive exploration showing mathematics from different points of view, discussion of problems offering more than one solving process, and peer discussions making the students come to terms with different opinions and ways of understanding are among the features that can provide learners with experience in and appreciation of multiple perspectives (Barana et al., 2019). In addition, teachers must be equipped with various abilities and skills to employ the right teaching methods and design interactive teaching materials to help students learn mathematics comprehensively (Kamsurya, 2020). Interesting mathematics teaching strategies and learning activities will result in a better online learning experience for students Risdiyanti and Prahmana (2020).

Secondly and lastly, the students believed an enhanced feedback mechanism could have improved their online mathematics learning experience. Student 3 believed that "assessments should be returned without delay" as the feedback will "serve as a guide for the students in learning concepts and processes that they have answered or done incorrectly during tests." In the same way, Student 4 highlighted the importance of teachers' feedback, saying that "it helps a student grasp and have an in-depth understanding of the topics covered." She adds, "Given the nature of problems in mathematics, that they are usually not pure-

ly conceptual but procedural, seeing and receiving feedback from teachers about the right way to solve a given problem is crucial for students." Generally, the students recognized the value of being provided with prompt and timely feedback relative to the math problems they were asked to work on. According to Barana & Marchisio (2016), immediate feedback lets the students learn the problem-solving procedure independently. Also, it allows students to acknowledge their preparedness, providing them insight into the learning path they have undertaken, thus encouraging self-awareness in the knowledge construction process (Barana et al., 2019). Feedback is especially effective when it rapidly informs about the correctness of the answer, as it guides students to the solution through an active process.

3.2 Perspectives on Effective Online Mathematics Learning Environment

Given the students' experiences in their online mathematics classes, four overarching and major concepts surfaced as to what constitutes an effective online mathematics learning environment. They are (i) social presence, (ii) enriched online synchronous class, (iii) effective communication, and (iv) efficient feedback mechanisms.

Establishing an instructional relationship between teachers and students is crucial in an online learning environment. As shared by the students, they needed to be able to interact with their teachers and classmates, especially during synchronous classes. It makes them feel motivated to learn and actively participate in activities as in the face-to-face setup. Also, perceiving the teacher's presence, such as regularly checking on them to see if they can follow in the discussion, adds to the learning support perceived by the students. Because online learning is more solitary, students reported feeling disconnected from the class (Rowntree, 2000, as cited in Jones et al., 2008). Thus, for teachers, the challenge in designing an online class is establishing their teaching presence. It involves course design, dialogue facilitation, and the development and implementation of activities that will encourage interaction between the teacher and the students (Jones et al., 2008). As emphasized by Song (2022), "Effective online teaching requires building social relationships and establishing emotional security to promote dialogue and create a collaborative learning community."

Another attribute of an effective online mathematics class, as perceived by the students, is the enriched facilitation of online synchronous classes. It was apparent in the sharing made by the students how they put value in their active engagement during online classes; online engagements can be in recitations, collaborative activities with their classmates, and dynamic interaction with their teacher. In a 2021 study by Bakker et al., among the teaching strategies and types of learning to be promoted in the mathematics education landscape in the next ten years, one is collaborative learning, among others. Chiu et al. (2021) raised promoting technology-supported social and collaborative environments for peer mutual support. Their research pointed out collaborative learning is a prerequisite for an online course. Thus, teachers need to build a learning community designed with collaborative learning activities. Especially in mathematics, collaborative problem-solving has been recognized to

facilitate thinking and understanding among students (Calder et al., 2021).

Attention should also be paid to effective communication, which, in this study's context, involves various communication platforms, active and open communication between the teacher and the students, and timely feedback. From the data gathered, the different means of communication, such as email, FB messenger, and Canvas inbox, helped the students seek assistance from their teachers, especially beyond online class hours. It paved the way for active and open communication with their teachers. However, although the students acknowledged the teachers' responsiveness to their inquiries, the delay in giving feedback on the assessments was a significant issue. As reported by Bakker and Wagner (2020), the unprecedented urgent demand to shift to fully online classes formed new boundaries: physical distance and lack of easy communication and access. In online learning, communication and interactivity are fundamental because they facilitate the formation of an effective learning relationship between the students and the teacher (Reju, 2016), along with the assimilation of the course contents during the learning process through prompt feedbacks (Barana & Marchisio, 2016). Reju emphasized that "the understanding of mathematical concepts depends on how they communicate to the learners" (p.163). Thus, educational institutions must enhance all communication platforms and accessible technologies that encourage student-student and teacher-student interactions.

Finally, an effective online mathematics learning environment for students is characterized by an efficient feedback mechanism. In this study, efficient feedback entails prompt giving of feedback by the teachers to the students and open communication between the teacher and students where clarifications are welcome anytime. While it is recognized that teachers are particularly challenged to provide feedback when there is no face-to-face interaction, for students, the importance of receiving feedback through active and open communication with their teachers must be considered. In the FGD, needing timely feedback was one of the obstacles raised by the students. Additionally, the students expected test scores to come with explanations explaining why they got incorrect answers. Feedback is the information given by teachers about the performance of students by which they can improve their performance (Gopal et al., 2021). When a student faces a problem understanding concepts, he must inquire about the teacher's solutions (Bangert, 2004). It has been found that prompt feedback helps develop a strong linkage between teacher and students, eventually enhancing the student learning experience (Gopal et al., 2021). Good feedback practice is beneficial for students and thus should be observed by teachers for a better student learning experience.

Subcomponents were found to be underlying the four components that make up an effective online mathematics learning environment. These are teacher-student interaction, student-student interaction, teacher's presence, recitations, open communication, various communication platforms, and timely feedback. It is worth mentioning that most of these subcomponents are present in two or more components. To wit, the teacher-student interaction is vital to an effective online mathematics learning environment, as

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the results indicate it is present in all four components mentioned. On the other hand, student-student interaction established its significance in two components, social presence and enriched synchronous class, as with open communication and timely feedback that emerged as considerable subcomponents in effective communication and enhanced feedback mechanism. Further, while the four components have commonalities, there are still subcomponents identified to be unique: the teacher's presence for social presence, recitations concerning enriched synchronous class, and various communication platforms for effective communication.

3.3 Proposed Model for Online Mathematics Learning Environment

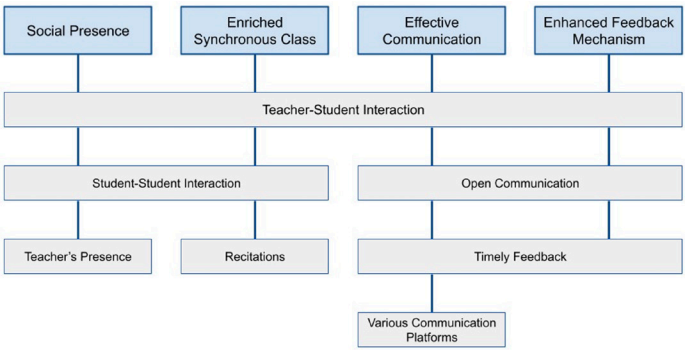

Figure 1. Model for Online Mathematics Learning Environment

Based on the themes that surfaced in the learning experiences shared by the students, the above is the proposed model for an online mathematics learning environment. A learning environment is a space where students feel safe, inspired, and supported in their learning journey by their surroundings (Western Governors University, 2021). This study's model encompasses the four components that characterize an effective online mathematics learning environment—social presence, enriched synchronous class, effective communication, and enhanced feedback mechanism. The model also captures the relevant subcomponents embodied in the four components.

A subcomponent of all four components, the teacher-student interaction, is vital in an online mathematics learning environment. The interaction between the teacher and the students is basic in attaining social presence and effective communication. Likewise, for an enriched synchronous class to succeed, there should be a dynamic interaction between the teacher and students, which will then translate to the frequency and timeliness of feedback. If the students can interact frequently with the teacher and vice versa, an enhanced feedback mechanism is achieved.

The student-student interaction is portrayed to be a subject of concern in both social presence and enriched synchronous class components. Equally important to teacher-student interaction is the student-student interaction in the context of social presence. The case is similar in an enriched synchronous class, as online engagements involve student recitations and collaborative activities among students. Additionally, from the model, open communication and timely feedback, are both presented as subcomponents of effective communication and enhanced feedback mechanism, In an online learning setting, one feature of effective communication is ensuring that lines of communication remain open (Radmehr & Goodchild, 2021), whether during class hours or not. This applies as well to giving and receiving feedback. For an enhanced feedback mechanism to be realized, the students should be able to communicate openly with their teachers. Aside

from keeping the lines of communication open, timely feedback was likewise associated with effective communication. Timely feedback is tantamount to information provided without delay, thereby improving the process of giving feedback.

The teacher's presence, recitations, and various communication platforms are unique to their respective components, establishing each component's distinctiveness. As one of the subcomponents of social presence, the teacher's presence impacts the students' learning experiences. It suggests to the students that they are well-guided and that they make progress with the teacher. As with recitations, students need many opportunities to participate actively during online classes. This makes the learning experience more engaging for them. And lastly, the various communication platforms subcomponent completes the aspects relevant to effective communication. Having different means of communication helps break the boundaries formed in an online learning setting, including a need for easier communication and access (Bakker & Wagner, 2020).

CONCLUSION AND RECOMMENDATIONS

The COVID-19 pandemic has caused massive disruption in the teaching and learning process of higher education institutions worldwide. This has led to a forceful shift from a predominantly face-to-face setup to a full online learning modality. The study contributes to understanding students' learning experiences and highlights the strengths, weaknesses, opportunities, and threats identified in mathematics online learning. Also, a viewpoint on what constitutes an effective online mathematics learning environment is provided.

The experiences of students reported in this study relate to the following areas: learning support of the school, communication and information dissemination, feedback on assessments and activities, studying and preparing for course requirements, change in one's self brought about by online learning, and digital literacy among teachers and students. Based on the thematic categorization of students' learning, findings revealed that social presence, enriched online synchronous class, effective communication, and enhanced feedback mechanism compose an effective online mathematics learning environment. A model for an online mathematics learning environment was proposed to provide a useful lens to analyze the relationships among the four components and their subcomponents.

This work adds to the information regarding mathematics online learning during the COVID-19 pandemic. The results of this study offer a standpoint, in the Philippine context, on where educational governing bodies, higher education institutions, and teachers should focus on designing an online mathematics learning environment that will provide positive and meaningful learning experiences for the students. For future research, it is recommended that the proposed

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