

Original Article

Lived Experiences of Graduate Students in Understanding Core Mathematics Subjects Through Online Modality

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Abstract. This study explored the lived experiences of graduate mathematics students in understanding core mathematics subjects through online modality. Guided by a qualitative phenomenological design, the research captured the challenges, coping strategies, and insights of second-year graduate students enrolled in advanced courses such as Set Theory, Number Theory, Abstract Algebra, Modern Algebra, and Advanced Geometry. A purposive sample of participants from selected higher education institutions participated in in-depth interviews, and data were analyzed using thematic analysis. Findings revealed two major dimensions of online learning experiences: negative and positive. Students encountered significant challenges, including unstable internet connectivity, limited interaction with instructors and peers, difficulty in understanding abstract and complex mathematical concepts, and learning fatigue. These challenges contributed to cognitive overload, decreased motivation, and emotional frustration. Despite these difficulties, students demonstrated adaptive coping mechanisms such as self-discipline, independent learning, resilience, and persistence. Their emotional experiences shifted between discouragement and fulfillment as they navigated and overcame learning obstacles. The findings contribute to the existing literature on constructivism, self-regulated learning, and online collaborative learning by contextualizing these frameworks within the domain of advanced mathematics education in an online learning environment.

Keywords: Graduate mathematics students; Lived experiences; Mathematics core subjects; Online learning

The rapid advancement of digital technologies has significantly transformed higher education, leading to the increasing adoption of online learning modalities in graduate programs worldwide. While online education offers flexibility and broader access to learning opportunities, it also presents unique challenges for teaching and learning complex disciplines such as mathematics. Graduate-level mathematics courses require deep conceptual understanding, logical reasoning, and sustained interaction between instructors and students. However, the use of digital platforms such as video lectures, self-paced modules, and online discussion boards may limit real-time engagement, making it more difficult for instructors to communicate abstract mathematical

concepts effectively. In the absence of immediate interaction, students may have difficulty asking spontaneous questions or clarifying complex ideas, hindering comprehension and meaningful learning.

Studies have shown that graduate students in online learning environments often encounter a range of academic and psychological challenges. For instance, Zhang et al. (2024) reported that students experienced reduced motivation, heightened anxiety, and difficulty managing their own learning processes in virtual settings. These challenges are often intensified by the lack of a structured academic environment and limited peer interaction, both of which are essential in sustaining effective learning experiences.

Similarly, research conducted in various Asian educational contexts highlights persistent issues in online mathematics learning. Graduate mathematics students frequently encounter technological constraints, limitations in instructional delivery, and individual learning difficulties when studying through online platforms. (Bushe & Maluleke., 2023) emphasized that the global digital divide continues to affect students' participation in online mathematics courses due to unreliable internet connectivity and the absence of conducive learning environments. Pokrhel (2023) also stated that insufficient digital infrastructure and restricted access to online resources have posed major obstacles to students' learning. In addition, Rapanta et al. (2020) noted that limited access to instructors and reduced peer interaction can hinder students' engagement with abstract mathematical concepts, particularly in asynchronous learning environments.

In the Philippine context, these challenges are further intensified by technological and environmental limitations. (Mamolo, 2022) emphasized that mathematics education requires interactive problem-solving, immediate feedback, and continuous dialogue between instructors and students, elements that are difficult to replicate in fully online environments. Consequently, graduate students often have difficulty understanding complex mathematical concepts and sustaining engagement during online classes. Moreover, Fabito et al. (2020) found that communication barriers in virtual learning environments limit students' ability to seek clarification, as the absence of non-verbal cues and real-time interaction may lead to misunderstandings and weaker conceptual understanding.

Despite these challenges, previous studies have identified coping strategies that enable students to navigate online learning environments. (Salubayba, 2021) found that graduate students relied on peer support, family assistance, and academic mentoring to manage the demands of online learning. Additionally, self-regulated learning strategies, effective time management, and the use of digital tools have been shown to help students balance academic and personal responsibilities.

However, despite the growing body of literature on online learning in higher education, there remains a notable gap in research focusing specifically on the lived experiences of graduate mathematics students engaged in advanced, proof-based core subjects within online learning environments, particularly in the Philippine context. Existing studies tend to examine general online learning challenges or undergraduate populations, with limited attention given to the unique cognitive, emotional, and academic experiences of graduate students dealing with abstract and theoretically demanding mathematical content. This gap highlights the need for a deeper, experience-based understanding of how graduate mathematics students navigate and make sense of online learning in core subject areas.

Therefore, this study aims to explore the lived experiences of graduate students enrolled in the Master of Arts in Education major in Mathematics Teaching program as they engage with core mathematics subjects through online learning modalities. Specifically, this study seeks to answer the following research questions:

1. What are the lived experiences of graduate mathematics students in understanding core mathematics subjects through online learning modalities?
2. What challenges do they encounter in the process?
3. What coping strategies do they employ to address these challenges?
4. What insights can be drawn from their experiences to improve online mathematics instruction?

By addressing these questions, the study aims to deepen understanding of graduate mathematics learning in online environments and provide practical insights to improve instructional practices and support systems in higher education.

Methodology

Research Design

This study employed a qualitative research design to explore the lived experiences of graduate mathematics students in learning core subjects through online instruction. Qualitative research aims to investigate, understand, and interpret social phenomena within their natural contexts (Creswell & Poth, 2022). This approach enabled the researcher to obtain rich and in-depth descriptions of the participants' experiences, perceptions, and challenges in an online learning environment.

Specifically, the study utilized a descriptive phenomenological approach, which focuses on describing the common meaning of a lived experience shared by several individuals (Moustakas, 1994). This approach is appropriate for examining how individuals consciously experience a particular phenomenon while setting aside the researcher's preconceived assumptions through bracketing. In this study, the phenomenon under investigation was the experience of graduate mathematics students learning core subjects through online modality.

Descriptive phenomenology seeks to uncover and describe the essence of participants' experiences by analyzing their narratives and identifying significant statements, themes, and meanings. Through this approach, the researcher collected detailed accounts from participants and systematically analyzed them to determine common patterns and shared meanings. This enabled the study to capture how graduate mathematics students experienced online learning, the challenges they encountered, and the coping strategies they developed in dealing with advanced and abstract mathematical concepts in a virtual environment.

Participants and Sampling Technique

This study employed purposive sampling, a non-probability sampling technique commonly used in qualitative research to select participants who possess specific knowledge or experience relevant to the phenomenon under investigation (Creswell & Poth, 2022; Stratton, 2024). This approach was deemed appropriate as the study aimed to explore the lived experiences of graduate mathematics students who have engaged in learning core mathematics subjects through online modality. By intentionally selecting information-rich participants, the researcher obtained in-depth and meaningful insights into the phenomenon.

The participants of the study were graduate students enrolled in the Master of Arts in Education major in Mathematics program from selected Higher Education Institutions (HEIs), namely: Davao del Sur State College (DSSC), University of Southeastern Philippines – Davao City Campus (USEP), University of Mindanao – Digos Campus (UMDC), and Cor Jesu College (CJC). A total of twelve (12) participants were included, with three participants from each institution. The selection focused on second-year graduate students, as core mathematics subjects such as Set Theory, Number Theory, Abstract Algebra/Modern Algebra, and Advanced Geometry are typically offered during this stage of the program, making them the most suitable participants for the study.

To ensure consistency and relevance, the following inclusion criteria were applied: participants must (1) be officially enrolled in one of the identified HEIs during the first semester of School Year 2025–2026; (2) be second-year graduate students under the Master of Arts in Education major in Mathematics program; (3) have completed or are currently enrolled in at least one mathematics core subject delivered through online modality; and (4) be willing to voluntarily participate in the study.

Data collection continued until data saturation was achieved, indicating that no new significant insights emerged from additional interviews. While purposive sampling enabled the researcher to gather rich and relevant data, it also presents certain limitations. Since participants were intentionally selected based on specific criteria, the findings may not be generalizable to all graduate mathematics students. Additionally, there is a possibility of selection bias, as the sample may not fully represent the diversity of experiences across different contexts. Despite these limitations, purposive sampling remains appropriate for this study as it prioritizes depth of understanding over generalization.

Participant Demographic Profile

To provide context for the lived experiences examined in this study, the participants' demographic characteristics are presented in Table 1. These include age, gender, institutional affiliation, and years in graduate study. Presenting this information allows for a clearer understanding of the participants' backgrounds and enhances the

transparency and credibility of the findings. The demographic profile shows that the participants ranged in age from 26 to 43 years old, indicating a mix of early-career and more experienced graduate students. In terms of gender distribution, most participants were female (8 out of 12), while four (4) were male. All participants were in their second year of graduate study, ensuring they had sufficient exposure to core mathematics subjects delivered online.

Participant	Age	Gender	Institution	Years in Graduate Study
P1	35	Female	UMDC	2 years
P2	29	Female	UMDC	2 years
P3	31	Male	UMDC	2 years
P4	36	Female	USEP	2 years
P5	27	Female	USEP	2 years
P6	26	Male	USEP	2 years
P7	43	Female	CJC	2 years
P8	28	Female	CJC	2 years
P9	29	Female	CJC	2 years
P10	30	Female	DSSC	2 years
P11	27	Male	DSSC	2 years
P12	32	Male	DSSC	2 years

In terms of institutional representation, participants were evenly distributed across four Higher Education Institutions: the University of Mindanao – Digos Campus (UMDC), University of Southeastern Philippines (USEP), Cor Jesu College (CJC), and Davao del Sur State College (DSSC). This distribution provided a diverse range of experiences and learning contexts, strengthening the credibility and transferability of the findings.

Research Instrument

Data were collected through in-depth semi-structured interviews. An interview guide was developed to facilitate the discussion and ensure that all relevant topics related to the participants' experiences were explored while still allowing flexibility for participants to elaborate on their responses. The interview guide consisted of open-ended questions designed to elicit detailed descriptions of participants' experiences learning core mathematics subjects through online instruction. The questions focused on areas such as learning difficulties, coping strategies, interaction with instructors, and perceptions of online mathematics learning. To ensure the clarity, relevance, and validity of the interview questions, the interview guide was reviewed and validated by experts in qualitative research and mathematics education. Their feedback and suggestions were incorporated to refine the questions before the actual data collection. With the participants' consent, the interviews were audio-recorded to ensure accurate capture of their responses. These recordings were later transcribed verbatim for analysis.

Data Gathering Procedure

Data were collected through in-depth face-to-face interviews with the selected participants. In-depth interviews are widely used in qualitative research because they allow participants to share detailed accounts of their experiences, perceptions, and interpretations of a particular phenomenon (Dursun, 2023). A preliminary survey was conducted among the identified Higher Education Institutions (HEIs) to determine whether the Master of Arts in Education major in Mathematics program was offered through online modality during the first semester of School Year 2025–2026. The researcher requested an endorsement letter from the Dean of the Graduate School to formally conduct the study. Approval was secured from the Institutional Ethics Review Board (IERB) or the appropriate approving body to ensure that the study complied with ethical research standards. Permission to conduct the study was requested from the heads of the participating institutions: Davao del Sur State College (DSSC), University of Southeastern Philippines – Davao City Campus (USEP), University of Mindanao – Digos Campus (UMDC), and Cor Jesu College (CJC). After approval, the researcher coordinated with the Dean of Graduate Studies and Program Heads to assist in identifying qualified participants based on the established inclusion criteria. Eligible participants were contacted and invited to participate in the study. The purpose of the study was clearly explained, and voluntary participation was emphasized.

Prior to the interviews, participants were provided with an informed consent form and were assured of confidentiality and anonymity. They were informed that they could decline to answer any question or withdraw from the study at any time without any negative consequences.

The interviews were conducted individually in a face-to-face setting at a time and place convenient for the participants. Each interview lasted approximately 30 to 60 minutes, depending on the depth of the participants' responses. A semi-structured interview guide was used to ensure consistency across interviews while allowing flexibility for participants to elaborate on their experiences. The interviews were conducted primarily in English and Cebuano, depending on participants' preferences, to facilitate clearer expression and understanding of their responses. During the interviews, the researcher asked open-ended questions and follow-up probes to elicit detailed narratives about the participants' experiences in learning core mathematics subjects through online modality. All interviews were audio-recorded with the participants' consent and were later transcribed verbatim. To ensure the credibility of the data, the transcripts were returned to the participants for member checking, allowing them to review and confirm the accuracy of their responses before the data were analyzed.

Data Analysis Procedure

The collected data were analyzed using thematic analysis, following the procedures outlined by Braun and Clarke (2023). Thematic analysis is a qualitative analytic method used to identify, analyze, and interpret patterns or themes within qualitative data.

The analysis followed the following steps:

1. *Familiarization with the Data* – The researcher repeatedly read the interview transcripts to gain a deeper understanding of the participants' experiences.
2. *Generating Initial Codes* – Significant statements and meaningful segments of the data were identified and coded.
3. *Searching for Themes* – Codes were examined and grouped to form potential themes that represented common experiences among participants.
4. *Reviewing Themes* – The themes were reviewed and refined to ensure that they accurately reflected the data.
5. *Defining and Naming Themes* – Each theme was clearly defined to capture the essence of the participants' experiences.
6. *Producing the Narrative Description* – The final themes were interpreted and presented to describe the shared experiences of graduate students learning mathematics core subjects through online modality.

This process involved systematically searching and organizing interview transcripts and other qualitative materials to gain a deeper understanding of the phenomenon under study. By synthesizing participants' accounts into meaningful statements, the researcher identified themes that captured the essence of their experiences. This method allowed for the linking of the most prevalent and significant themes to form an overall description of the participants' lived experiences (Christou, 2023).

Trustworthiness of the Study

To ensure the study's rigor and quality, the researcher established trustworthiness using Lincoln and Guba's four criteria: credibility, transferability, dependability, and confirmability.

Credibility was established through member checking, where participants reviewed the interview transcripts to verify the accuracy of their responses. Peer debriefing was also conducted by consulting research advisers and experts to review the data interpretation. It pertained to the confidence in the "truth" of the findings and reflected how well the research outcomes aligned with the participants' experiences and realities (Kakar et al., 2023).

Transferability was ensured by providing thick descriptions of the research context, participants, and procedures, enabling readers to determine whether the findings apply to similar contexts. To facilitate transferability, the researcher was encouraged to provide rich, detailed descriptions of the research context and participants, enabling readers to determine the relevance of the findings to their own settings (Enworo, 2023).

Dependability was maintained by documenting the research procedures, including data collection and analysis processes. This documentation created an audit trail that allows other researchers to understand how the findings were derived. This transparency enhanced the reliability of qualitative research findings and supported their applicability across different contexts (Megheirkouni & Moir, 2023).

Confirmability was ensured by maintaining neutrality in interpreting the data. Audio recordings, transcripts, and coded data were preserved to demonstrate that the findings were grounded in the participants' actual responses rather than the researcher's personal biases.

Ethical Considerations

Ethical considerations were strictly observed throughout the study to protect participants' rights, dignity, and overall well-being. This study was reviewed and approved by the Ethics Committee of Davao del Sur State College with decision number DSSC-IERB-2025-012 dated August 28, 2025.

Prior to data collection, participants were provided with a written informed consent form detailing the purpose of the study, research procedures, and their rights as participants. They were clearly informed that participation was entirely voluntary and that they could decline to answer any question or withdraw from the study at any time without any negative consequences.

To ensure privacy and confidentiality, participants' identities were protected by using pseudonyms in all transcripts and research reports. Any identifying information was removed to maintain anonymity. All collected data, including audio recordings and transcripts, were securely stored in password-protected files accessible only to the researcher. Furthermore, the data will be retained only for a specified period and properly disposed of upon completion of the study.

In addition, the researcher ensured that no harm, physical, psychological, or emotional, was inflicted on the participants during the study. The interviews were conducted in a respectful and non-threatening manner, allowing participants to express their experiences freely. The researcher also maintained honesty, transparency, and integrity throughout the research process to uphold ethical research standards.

Results and Discussion

The analysis revealed recurring patterns that illustrate how graduate students navigated the cognitive, technological, and emotional demands of learning advanced mathematics in an online environment. The findings underscore both the challenges encountered and the adaptive strategies developed by learners in response to these difficulties. The study focuses on core mathematics subjects, including Set Theory, Number Theory, Abstract Algebra, and Advanced Geometry. However, some participants also referenced related advanced mathematical topics as part of their broader learning experiences.

Challenges Encountered While Studying Core Mathematics Subjects Online

Technological and Instructional Barriers in Online Mathematics Learning

Graduate mathematics students described technological and instructional limitations as significant barriers that interfered with their ability to engage meaningfully with mathematical content. In an online environment where learning heavily depends on digital tools, disruptions in connectivity, unclear visual materials, and limited interaction were experienced as obstacles to understanding rather than mere inconveniences. Mathematics requires clarity, precision, and step-by-step reasoning. When instructional delivery is affected by poor internet connection or unclear visual aids, students find it difficult to follow the logical progression of solutions and proofs.

Disruptions in Understanding Due to Poor Connectivity and Visual Limitations. A common experience among participants was the difficulty of interpreting mathematical representations when online instruction was affected by lagging video, blurred screen sharing, or intermittent connectivity.

"Sometimes, the screen freezes right at the most important part of the solution. When that happens, I feel lost because I miss the step where everything connects. Even if I try to follow after, it's hard to understand the whole process anymore, especially in proofs where every step is important." (P2)

"Sometimes the video lags, or I get cut off from the live class, especially during complex topics. When I reconnect, I feel like I'm already behind, and it's difficult to catch up because I missed the explanation that links the steps together." (P10)

These accounts suggest that technological disruptions extend beyond access issues and fundamentally interrupt the continuity of mathematical reasoning. In graduate mathematics, where understanding depends on sequential

logic and interconnected steps, missing a critical portion of explanation results in cognitive fragmentation. As a result, learners experience confusion and difficulty reconstructing meaning, which weakens their confidence in engaging with abstract and symbolic processes. These disruptions are experienced as breaks in the flow of thinking, where students are unable to sustain the logical progression necessary for deep conceptual understanding.

Limited Interaction and Delayed Feedback. Participants also described difficulties in engaging with instructors and seeking clarification during online classes.

"I wanted to ask a question, but my internet was slow, and my audio kept cutting off. I felt embarrassed because my voice kept repeating, so I just stopped trying. After the class, I was left confused because I didn't get a clear explanation." (P1)

"Online, I had to wait for replies, and sometimes I hesitated to ask because I was unsure if the teacher would respond right away. There were times when I kept my questions to myself and tried to figure things out on my own." (P5)

These experiences indicate that limited interaction not only delays clarification but also affects students' willingness to participate. The absence of immediate feedback creates a gap between confusion and understanding, forcing students to rely on their own interpretations. This suggests that real-time engagement is critical in mathematics learning, where concepts often require immediate clarification. Without it, students experience prolonged uncertainty, which can lead to misconceptions and an incomplete understanding of multi-step reasoning processes.

Technological and instructional barriers are not isolated challenges but interconnected disruptions that directly affect students' ability to sustain mathematical reasoning. In core mathematics subjects such as Set Theory and Abstract Algebra, where understanding relies on sequential logic and precise symbolic representation, the absence of stable connectivity, clear visualization, and immediate feedback creates cumulative difficulties. These challenges not only hinder comprehension but also weaken students' confidence in engaging with complex mathematical processes.

Cognitive Difficulties in Understanding Abstract Mathematics

Participants described significant challenges in understanding abstract and highly symbolic mathematical concepts in an online setting. Core mathematics subjects such as Set Theory, Abstract Algebra, and Advanced Geometry require sequential reasoning, visualization, and guided explanation—elements that are often limited in virtual learning environments.

Struggles with Abstract and Theoretical Concepts. Participants emphasized the difficulty of following proofs, symbolic representations, and multi-step procedures without direct guidance.

"The hardest parts were the abstract concepts and proofs. There were so many symbols and logical steps that needed to be clearly seen and explained. When it's online, I sometimes don't fully understand how one step leads to another." (P1)

"In Abstract Algebra, the proofs had so many steps. If I missed even one part of the explanation, I couldn't follow the rest anymore. It made me feel confused and unsure if I was understanding correctly." (P2)

These narratives suggest that the difficulties encountered were not only cognitive but also deeply experiential. Students described a sense of disorientation when they were unable to follow the progression of ideas, particularly in subjects that require continuous logical reasoning. Misunderstanding even a single step often results in cascading confusion, where the inability to grasp one concept affects the comprehension of subsequent steps. This highlights how mathematical understanding is built on continuity, making disruptions particularly detrimental in an online setting.

These experiences reflect how learners encounter abstraction not merely as an intellectual difficulty but as a breakdown in meaning-making, where the absence of guided explanation intensifies cognitive strain.

Taken together, these findings indicate that the cognitive demands of graduate mathematics are intensified in online learning environments. In core mathematics subjects such as Advanced Geometry and Abstract Algebra, where abstract reasoning and multi-step proofs are essential, disruptions in explanation and visualization significantly affect students' ability to construct meaning. The findings further highlight that mathematical understanding is highly dependent on continuity; when this continuity is compromised, students experience both cognitive overload and conceptual disorientation.

Environmental and Motivational Challenges in Online Learning

Beyond technological and cognitive barriers, participants also described how their home environment and emotional state influenced their learning experiences. Distractions and declining motivation affected their ability to focus, engage, and sustain effort.

Disruptions from the Home Learning Environment. Participants reported that noise, household responsibilities, and unexpected interruptions affected their concentration during online classes.

"There were distractions at home, such as noise, people talking, and chores. Sometimes, even if I wanted to focus, something would interrupt me, and I would lose track of what the teacher was explaining." (P1)

"Distractions are difficult to control, especially since I have a baby. There are times when I have to stop listening to the discussion, and when I return, I have already missed important parts." (P3)

These experiences suggest that environmental interruptions disrupt not only attention but also the continuity of cognitive processing. In mathematics, where sustained focus is required to follow multi-step reasoning, even brief distractions can significantly affect comprehension. The learning environment becomes an active factor in shaping understanding, where external interruptions translate into internal breaks in reasoning and meaning construction.

Learning Fatigue and Declining Motivation. Participants also experienced mental fatigue and reduced motivation due to prolonged screen time, limited interaction, and continuous academic demands.

"I felt unmotivated because even if I attended the class, the connection would cut off, and I could not follow the lesson properly. It made me feel like my effort was wasted, so sometimes I did not feel like attending anymore." (P1)

"I felt tired and discouraged because even when I tried to focus, there were too many interruptions. It became difficult to stay motivated, especially when I did not fully understand the lesson." (P3)

These reflections indicate that motivation is closely tied to students' perceived ability to successfully engage with learning tasks. When repeated barriers prevent understanding, students begin to associate effort with limited outcomes, leading to disengagement. Demotivation is not simply a lack of interest but a response to sustained difficulty in achieving meaningful understanding, particularly in cognitively demanding subjects such as mathematics.

These findings demonstrate that environmental and motivational factors play a critical role in shaping students' learning experiences in online mathematics education. Distractions and fatigue do not merely affect attention but also disrupt the sustained cognitive engagement required in core mathematics subjects. As a result, students' ability to follow complex reasoning processes and maintain motivation is significantly influenced by both their learning environment and emotional state.

Strategies Used by Students to Overcome Difficulties in Understanding Core Mathematics in Online Classes ***Self-Directed Learning Practices***

Graduate mathematics students developed independent learning strategies to compensate for limited instructor interaction and disruptions in online instruction. This reflects a shift toward learner autonomy, where students actively regulate their own understanding.

Utilizing Multiple Learning Resources. Participants described actively seeking alternative explanations and materials to better understand difficult concepts.

"If I do not understand the professor's explanation, I search for YouTube tutorials because they provide step-by-step solutions. Sometimes they explain the concepts in a simpler way, which helps me understand better. I also check forums and other materials to compare different explanations." (P1)

"YouTube tutorials and online forums helped me a lot because they provided different approaches. When one explanation does not work for me, I look for another until I understand." (P2)

These experiences suggest that students actively reconstruct understanding through multiple sources rather than relying solely on instructor explanations. This process reflects a deliberate effort to bridge comprehension gaps and maintain continuity in learning. This demonstrates a shift toward learner agency, where understanding is actively pursued, negotiated, and validated through exploration and comparison.

Managing Time and Minimizing Distractions. Participants emphasized the importance of structuring their study time and controlling distractions.

"During study time, I made sure to avoid distractions. I prepared everything I needed so I would not lose focus once I started studying." (P4)

"I turned off notifications and looked for a quiet place because I knew that even small distractions could affect my understanding." (P5)

These accounts indicate that students recognized the need to actively control their environment to sustain engagement. Managing distractions becomes a strategic response to preserve cognitive continuity. This suggests that self-regulation extends beyond time management and includes deliberate environmental control to support deep learning.

Overall, these findings suggest that self-directed learning is not merely a response to instructional limitations but a critical component of success in online mathematics learning. In the absence of continuous teacher guidance, students develop the capacity to regulate their own understanding, particularly in complex subjects such as Set Theory and Number Theory. This shift highlights the role of learner autonomy in sustaining conceptual development in virtual environments.

Collaborative Learning and Peer Support

Students relied on peer interaction as an important source of academic and emotional support.

Engaging in Peer Discussions to Co-Construct Understanding. These experiences suggest that collaboration functions as a shared space for meaning-making. Through discussion, students clarify misunderstandings and reinforce their own understanding. This indicates that learning becomes a collective process in which knowledge is co-constructed, reducing feelings of isolation and increasing confidence.

"We had group chats and video calls where we discussed problems step by step. When I did not understand something, my classmates explained it in different ways, which helped me a lot." (P1)

"We divided difficult problems and explained them to each other. When I explained my solution, I realized whether I truly understood it or not." (P5)

Overall, collaboration serves as both a cognitive and emotional support system in online learning. Through peer interaction, students are able to clarify misunderstandings, validate solutions, and maintain engagement in complex mathematical tasks. This underscores the importance of social learning processes even in virtual learning environments.

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Emotional Regulation and Persistence in Learning Mathematics

Participants emphasized the importance of perseverance and emotional control in overcoming learning difficulties.

Practicing Patience and Sustained Effort. These reflections indicate that persistence is a critical component of learning in challenging environments. Students described learning as a gradual process that requires repeated effort and tolerance for difficulty. Thus, persistence represents an ongoing engagement with uncertainty, where understanding is achieved through sustained effort rather than immediate clarity.

"I practiced patience because I knew that understanding mathematics takes time. Even when I felt confused, I would take a break and return to it later until I understood." (P4)

"I stayed consistent even when it was difficult because I did not want to fall behind. I kept trying until I understood the lesson." (P7)

These findings indicate that emotional regulation is integral to sustaining engagement in online mathematics learning. Persistence and patience enable students to navigate the inherent difficulty of abstract concepts, reinforcing the idea that learning mathematics is both a cognitive and emotional process. This highlights the importance of resilience in achieving understanding in challenging academic contexts.

Conclusion

This study explored the lived experiences of graduate students as they learned core mathematics subjects online, examining how they made sense of abstract mathematical concepts in a virtual learning environment. The findings provide a clearer understanding of how graduate students engage with core mathematics learning in online settings. The study reveals that the interaction of cognitive demands, technological conditions, and emotional responses shapes their experiences. These factors collectively influence how mathematical understanding is developed and sustained in an online context.

More importantly, the results show that the central inquiry of the study, how graduate students understand core mathematics subjects through online learning, is addressed through the ways students actively construct understanding despite instructional and environmental limitations. Understanding does not occur passively; rather, it emerges through continuous negotiation between difficulties and adaptive responses. While online learning presents challenges such as limited interaction, connectivity issues, and difficulty engaging with abstract mathematical structures, these conditions also prompt the development of essential academic competencies. Participants demonstrated self-regulation, persistence, collaborative engagement, and strategic use of learning resources as mechanisms to sustain mathematical understanding.

The study further highlights that meaningful online mathematics learning is not determined solely by access to digital platforms, but by the quality of instructional support that promotes conceptual clarity, interaction, and collaborative engagement. These elements are essential in enabling students to sustain logical reasoning and

deepen their understanding of advanced mathematical concepts. The study contributes to a deeper understanding of graduate mathematics education in online environments by showing that both constraints and adaptive processes shape students' learning experiences. It demonstrates that despite the limitations of virtual instruction, graduate students can develop strategies that support conceptual understanding, resilience, and independent learning in advanced mathematics.

Practical Implications

The findings suggest several practical considerations for improving the delivery of graduate mathematics courses in online environments.

Instructors should prioritize clear conceptual explanations, structured problem-solving demonstrations, and the use of visual and interactive tools to support students' understanding of abstract mathematical concepts. Integrating collaborative activities such as peer discussions, virtual problem-solving sessions, and structured feedback opportunities can strengthen both conceptual learning and student engagement.

Graduate learners benefit from cultivating self-regulated learning practices, including structured study routines, effective time management, and proactive use of multiple learning resources. Collaborative study groups and peer discussion spaces can also serve as important mechanisms for clarifying complex concepts and sustaining motivation in challenging courses.

Higher Education Institutions should strengthen the digital learning infrastructure and support systems that enable effective online mathematics instruction. This includes providing reliable platforms, interactive mathematical tools, accessible learning resources, and flexible learning policies that recognize the diverse circumstances of graduate students.

Collectively, these measures emphasize that improving online mathematics education requires coordinated efforts among instructors, students, and institutions to create learning environments that support both cognitive engagement and academic persistence.

Theoretical Implication

The findings of this study contribute to the broader understanding of learning in online environments by reinforcing and extending several established educational theories.

First, the results support Constructivist Learning Theory, demonstrating that students construct mathematical understanding through active engagement with problems, digital resources, and collaborative interactions. Even within online environments, meaningful learning emerges when students are able to connect new mathematical ideas with prior knowledge through guided exploration and discussion.

Second, the findings highlight the relevance of Self-Regulated Learning Theory in graduate mathematics education. Students' ability to plan their learning activities, monitor their progress, and persist despite conceptual difficulties illustrates how self-regulation becomes a critical factor in mastering abstract and cognitively demanding subjects in online contexts.

Finally, the study aligns with Online Collaborative Learning (OCL) Theory, which emphasizes the role of technology-mediated interaction in knowledge construction. Participants' reliance on peer discussion and collaborative problem-solving suggests that collective reasoning and shared interpretation remain essential for understanding complex mathematical concepts, even when learning occurs virtually.

Taken together, these theoretical perspectives suggest that effective online graduate mathematics learning emerges from the interaction of learner autonomy, collaborative knowledge building, and well-designed instructional support. By situating graduate students' lived experiences within these frameworks, the study provides a deeper understanding of how theoretical principles operate in the context of advanced mathematics education delivered through online modalities.

Contributions of Authors

Author 1: conceptualization of the study, contributed to the development of the research design, and took the primary role in writing and finalizing the manuscript.

Author 2: research adviser, providing supervision, critical revisions, and guidance in the overall development of the study.
Author 3: refinement of the research methodology and provided input on instructional and pedagogical aspects of the study.
Author 4: assisted in the validation of the research framework and contributed to the interpretation of results and academic review of the manuscript.
Author 5: supported the study through research coordination, technical input, and assistance in ensuring compliance with research standards and publication requirements.

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Conflict of Interests

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