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Pandemic's Aftermath: Online Learning's Influence on Current Mathematics Proficiency and Inclusive Learning Recovery among Senior High School STEM Students

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ABSTRACT

This study explored how pandemic-era online learning influenced the current mathematics proficiency and inclusive learning recovery needs of Grade 11 STEM students. Using a qualitative phenomenological approach, in-depth interviews were conducted with seven purposively selected students from Sultan Kudarat State University - Laboratory High School. Findings revealed that poor internet access, limited teacher interaction, distracting home environments, and reduced feedback weakened students' foundational mathematics skills during Grades 7 and 8. Participants reported persistent gaps in understanding advanced concepts, decreased confidence, stress, and anxiety. Although some developed self-directed learning strategies, most preferred face-to-face instruction. The study highlights the need for inclusive remedial mathematics programs, learner-centered support, and emotionally responsive interventions after pandemic-related learning disruption.

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1. INTRODUCTION

Mathematics plays an essential role in Science, Technology, Engineering, and Mathematics (STEM) education because it develops logical reasoning, problem-solving ability, analytical thinking, and readiness for higher-level scientific learning. Previous studies on mathematics and STEM education have examined mathematical achievement, problem-solving skills, mathematics readiness, online academic performance, student interest, differentiated instruction, computational and mathematical thinking, and factors affecting students' mathematics performance (Sabugal and Apellido, 2025; Lagcao *et al.*, 2023; Jose, 2022; Dermawan *et al.*, 2022; Camilon *et al.*, 2025; Abidin *et al.*, 2025; Lasisi *et al.*, 2024; Padmore and Ali, 2024). A strong mathematical foundation is especially important for senior high school STEM students, who are expected to engage with advanced concepts in algebra, geometry, statistics, calculus, physics, chemistry, and other science-related fields. When foundational mathematical skills are weak, students may experience difficulty understanding complex lessons and may lose confidence in their academic abilities. Previous studies have emphasized that mathematics is central to STEM learning and that early mastery of mathematical concepts supports success in advanced academic pathways (Just and Siller, 2022).

The COVID-19 pandemic disrupted traditional face-to-face instruction and forced many schools to shift to online or distance learning. Although online learning allowed education to continue during school closures, it also created serious challenges for students, teachers, and families. Students often experienced unstable internet connectivity, limited access to devices, reduced teacher interaction, distractions at home, and difficulty maintaining motivation. These challenges were especially significant in mathematics, where students often need step-by-step explanations, immediate feedback, guided practice, and teacher support to understand abstract and sequential concepts. Studies during the pandemic reported that online learning affected students' engagement, learning continuity, and academic performance (Elzainy *et al.*, 2020; Kanneganti *et al.*, 2020; Talimodao and Madrigal, 2021).

For students who were in Grades 7 and 8 during the pandemic, the disruption may have had long-term effects because these grade levels are important for developing foundational mathematics skills. Concepts learned during these years often serve as prerequisites for senior high school STEM mathematics. If students did not fully master basic skills during online learning, they may experience difficulties when facing more advanced topics later. These learning gaps may affect not only academic performance but also confidence, motivation, participation, and emotional well-being in mathematics classes.

The issue is also relevant to inclusive education and learning recovery. Students did not experience online learning in the same way. Some had stable internet access, quiet study spaces, and family support, while others faced limited resources, emotional stress, household responsibilities, or difficulty learning independently. These unequal conditions may have created different levels of learning loss and recovery needs. Therefore, post-pandemic mathematics education should not only focus on academic remediation but also on inclusive learning recovery that considers students' access, confidence, emotional struggles, and need for supportive instruction.

Although several studies have examined online learning during the pandemic, there remains a need to understand how students themselves describe its long-term effects on their present mathematics proficiency. In particular, limited attention has been given to the

experiences of senior high school STEM students who are now expected to perform in advanced mathematics after experiencing online learning during critical foundational years. Their reflections can provide important insights for designing inclusive remedial programs, supportive teaching strategies, and recovery interventions that address both academic and emotional learning needs.

This study explored the influence of pandemic-era online learning on the current mathematics proficiency and inclusive learning recovery needs of senior high school STEM students. Specifically, it sought to answer the following questions:

(i) How do senior high school STEM students describe their experiences with online learning in Mathematics during the pandemic?
(ii) How do they perceive the effectiveness of online learning in relation to their foundational mathematical knowledge and skills?
(iii) In what ways do they believe their pandemic-era online learning experiences have prepared or hindered their current performance in advanced mathematics concepts?

2. METHODS

This study used a qualitative phenomenological research design to explore the lived experiences of senior high school STEM students regarding pandemic-era online learning and its influence on their current mathematics proficiency. A phenomenological approach was appropriate because the study focused on students' personal experiences, perceptions, challenges, coping strategies, and meanings attached to learning Mathematics online during the COVID-19 pandemic.

The study was conducted at Sultan Kudarat State University - Laboratory High School, Philippines. Seven Grade 11 STEM students were purposively selected as participants. They were chosen because they had experienced online learning during Grades 7 and 8, which are important years for developing foundational mathematics skills, and were currently enrolled in senior high school STEM, where they were expected to engage with more advanced mathematics concepts.

Data were collected through one-on-one in-depth interviews. Before data collection, approval was secured from the school principal, and the open-ended interview guide was validated by a panel of experts. Informed consent was obtained from all participants, and orientation sessions were conducted to explain the purpose of the study, interview procedures, confidentiality, voluntary participation, and the right to withdraw at any time. A trial interview was also conducted to refine the questions and improve the interview process.

The interviews were conducted at the participants' preferred time and in a comfortable setting. Each interview included one main question and three guide questions, with follow-up questions used for clarification when necessary. The sessions lasted approximately 20 to 60 minutes and were audio-recorded with permission to ensure accuracy. Participants were allowed to pause or stop the interview at any point if they felt uncomfortable.

The data gathering process followed several stages: communication with school authorities, obtaining participants' consent, orientation of participants, trial interview, actual interview, transcription, and member checking. This process is summarized in **Figure 1**. After the interviews, the audio recordings were transcribed, and member checking was conducted by allowing participants to review or confirm their responses. This step helped ensure that the data accurately reflected participants' experiences and perspectives.

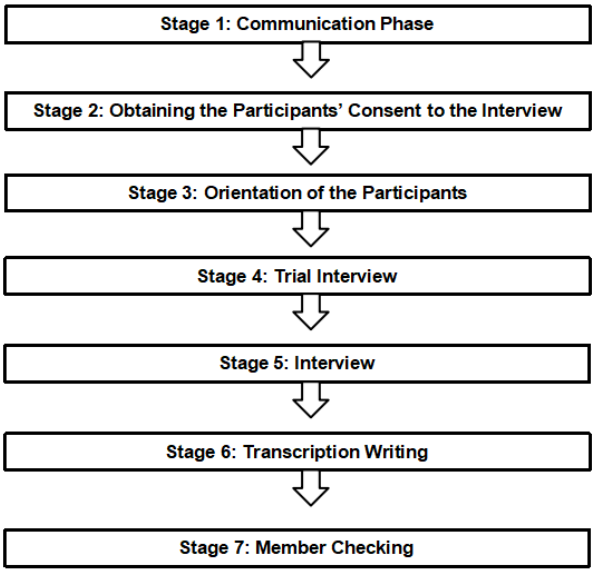

Figure 1. Waterfall diagram of the data gathering process.

The interview data were analyzed thematically. Responses were read repeatedly to identify recurring meanings related to online learning experiences, foundational mathematics gaps, teacher interaction, home learning barriers, emotional challenges, self-directed learning, and inclusive learning recovery needs. Similar responses were grouped into themes, and the themes were interpreted in relation to students' current mathematics proficiency and their need for supportive post-pandemic learning interventions.

Ethical considerations were observed throughout the study. Participants' identities and responses were kept confidential, and data were used only for research purposes. The study also considered the emotional sensitivity of discussing pandemic learning experiences, especially because some participants reported stress, anxiety, decreased confidence, and difficulty coping with advanced mathematics. Therefore, the interview process was conducted respectfully and with attention to students' well-being.

3. RESULTS AND DISCUSSION

Pandemic-era online learning had a lasting influence on the current mathematics proficiency of senior high school STEM students. Participants generally described their online Mathematics experience during Grades 7 and 8 as difficult, fragmented, and less effective than face-to-face learning. This finding supports previous studies showing that pandemic-related online learning created challenges in engagement, access, continuity, and academic performance, particularly when learners lacked stable resources and direct instructional support (Elzainy *et al.*, 2020; Kanneganti *et al.*, 2020; Talimodao and Madrigal, 2021). The major themes that emerged from the interviews are summarized in **Table 1**. The first major theme was limited access to effective online learning. Students reported that unstable internet connections, lack of suitable devices, and distractions at home made it difficult to focus during online Mathematics classes. These challenges reduced their ability to follow explanations, participate in discussions, and complete learning tasks consistently. Since Mathematics requires continuous practice, step-by-step explanation, and immediate clarification, access barriers weakened students' ability to fully understand lessons during the pandemic. This finding is consistent with studies reporting that pandemic-era distance learning exposed inequalities in access, implementation, and learning quality (Talimodao and Madrigal, 2021).

Table 1. Emergent themes on pandemic-era online learning and current mathematics proficiency.

THEME	STUDENTS' EXPERIENCE	EFFECT ON CURRENT MATHEMATICS PROFICIENCY	INCLUSIVE LEARNING RECOVERY IMPLICATION
Limited access to online learning	Students experienced unstable internet connections, limited devices, and distracting home environments.	Reduced ability to follow lessons and complete learning tasks consistently.	Provide flexible learning support, offline materials, and access-sensitive remediation.
Reduced teacher interaction	Students had fewer opportunities to ask questions, receive clarification, and get immediate feedback.	Weakened understanding of step-by-step problem-solving procedures.	Strengthen guided instruction, consultation time, and teacher-led feedback.
Foundational mathematics gaps	Students reported weak mastery of Grades 7 and 8 concepts such as factoring, graphing, and theorem application.	Difficulty understanding advanced Grade 11 STEM mathematics concepts.	Conduct diagnostic assessments and targeted remedial lessons.
Emotional and motivational challenges	Students experienced stress, anxiety, frustration, and decreased confidence in Mathematics.	Lower participation, reduced confidence, and difficulty coping with advanced lessons.	Include emotionally responsive teaching and confidence-building activities.
Self-directed coping strategies	Students used online tutorials, learning apps, and independent practice to cope.	Helped some students review concepts, but did not fully replace structured instruction.	Integrate teacher-guided digital resources and peer support.
Need for inclusive recovery	Students had different levels of learning loss depending on access, motivation, and home support.	Unequal readiness for current STEM mathematics learning.	Apply differentiated remediation and learner-centered recovery programs.

The second theme was the lack of teacher interaction and immediate feedback. Participants emphasized that online learning made it harder to ask questions, receive clarification, and follow problem-solving procedures. In face-to-face classes, students could observe the teacher's explanations, ask follow-up questions, and receive direct feedback. During online learning, however, many students felt that lessons were rushed, less interactive, or difficult to understand. This supports the view that mathematics learning requires strong instructional guidance because mathematical proficiency depends on conceptual clarity, procedural fluency, and repeated practice (Just and Siller, 2022).

The third theme was the development of foundational mathematics gaps. Students believed that their weak understanding of topics learned during Grades 7 and 8 affected their current ability to understand advanced Mathematics in Grade 11 STEM. They connected their present difficulties in algebra, graphing, factoring, theorem application, and other advanced topics to concepts they felt they had not fully mastered during online learning. Because mathematics concepts are cumulative, weak foundational mastery can affect students' later performance in STEM-related subjects (Just and Siller, 2022).

The fourth theme involved emotional and motivational challenges. Participants described stress, anxiety, frustration, and decreased confidence in Mathematics. Some students reported feeling less prepared for senior high school STEM subjects because their pandemic-era learning experience did not provide a strong foundation. This emotional dimension is important because learning recovery is not only about academic remediation; it also requires rebuilding students' confidence, motivation, and willingness to participate in Mathematics learning. Previous studies also noted that pandemic learning conditions affected student engagement and motivation (Elzainy *et al.*, 2020; Talimodao and Madrigal, 2021).

Despite these difficulties, the fifth theme showed that some students developed coping strategies. Participants used self-directed learning methods such as watching online tutorials, searching for additional explanations, reviewing digital materials, and practicing independently. These strategies helped some students manage learning gaps, but they were not enough to fully replace structured instruction. This indicates that online resources can support learning, but students still need teacher guidance, organized remediation, and clear learning pathways.

The final theme was the need for inclusive learning recovery. Students' experiences showed that pandemic-related learning loss was not the same for everyone. Learners with limited internet access, poor study environments, low confidence, emotional stress, or weaker foundational skills may require more intensive support. Therefore, post-pandemic Mathematics instruction should include diagnostic assessment, targeted remedial lessons, guided problem-solving, flexible learning support, peer tutoring, and emotionally responsive teaching. These interventions are important because inclusive learning recovery should respond to students' varied academic gaps, emotional needs, access limitations, and learning support requirements.

Online learning during the pandemic negatively affected students' foundational Mathematics proficiency, particularly because of limited access, reduced interaction, and insufficient feedback. However, the results also show that students developed some independence and resourcefulness through self-directed learning. The key implication is that post-pandemic Mathematics education should be inclusive and recovery-oriented. Schools should not only reteach missed competencies but also provide differentiated support for students with varied learning gaps, emotional needs, and access-related challenges.

4. CONCLUSION

Pandemic-era online learning had a lasting influence on the current mathematics proficiency of senior high school STEM students. Participants described their online Mathematics experience during Grades 7 and 8 as difficult because of unstable internet access, limited learning devices, distracting home environments, reduced teacher interaction, and a lack of immediate feedback. These barriers weakened their understanding of foundational Mathematics concepts that are needed for more advanced STEM learning. Students experienced persistent learning gaps in topics such as factoring, graphing, theorem application, and other prerequisite skills. These gaps made advanced Mathematics more challenging and contributed to stress, anxiety, frustration, and decreased confidence. Although some students developed self-directed learning strategies by using online tutorials, digital materials, and independent practice, these strategies did not fully replace structured teacher guidance and classroom-based interaction. The study highlights the need for inclusive learning recovery in post-pandemic Mathematics education. Schools should provide

diagnostic assessment, targeted remedial instruction, guided problem-solving sessions, flexible learning support, peer tutoring, and emotionally responsive teaching. These interventions are important to support students with different levels of learning loss, access limitations, confidence issues, and academic recovery needs. Future studies may include a larger number of participants, compare different grade levels or school contexts, and examine the effectiveness of inclusive Mathematics recovery programs for students affected by pandemic-related learning disruption.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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