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Using gamification to re-engage students in Mathematics after online learning disruptions in the South African education system

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ABSTRACT

The modification to online learning during recent disruptions has notably affected student engagement in mathematics. This paper investigated gamification as a creative approach to rekindle interest in mathematical concepts and problem-solving skills in five secondary schools in the OR Tambo Coastal District of the Eastern Cape, South Africa.Through case studies and qualitative measures, the researcher illustrated how incorporating game elements into mathematics curricula creates a more interactive and engaging learning experience. The results suggest that gamification improves comprehension and retention of mathematical concepts by students while fostering a positive attitude towards learning. This study is grounded in Self-determination Theory, which posits that individuals are intrinsically motivated when three basic psychological needs are met: autonomy, competence, and relatedness. Using a qualitative research approach, the researchers engaged mathematics educators and Grade 10 learners to show the pedagogical, infrastructural, and socio-economic obstacles that hinder digital mathematics teaching and learning. Findings revealed that inequities in technology, limited digital skills, and the lack of interactive teaching methods significantly obstruct teaching effectiveness. Additionally, the ability of educators to adapt to digital platforms emerged as a crucial factor for instructional success, heavily reliant on institutional backing and professional development. The study highlights the urgent need for a comprehensive intervention that includes improved digital infrastructure, focused teacher training, and strong policy frameworks to address inequalities in online mathematics education. These findings contribute to the larger conversation on digital education equity and offer insights for sustainable e-learning strategies in the evolving post-pandemic educational landscape.

Keywords: Gamification, Mathematics Pedagogy, Technological Inequity, Online Instruction, Educational Resilience.

INTRODUCTION

The abrupt shift to online learning brought on by recent global disruptions such as the COVID-19 has significantly reshaped mathematics education, prompting the need for innovative approaches to reconnect students with learning. Conventional instructional strategies often fell short in virtual settings, creating challenges for educators in sustaining student attention and fostering interactive learning. Emerging research supports gamification as an effective tool to counter these issues, as it transforms

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abstract mathematical content into engaging, collaborative tasks that promote creativity and critical thinking. These skills are increasingly vital in today's educational landscape. Furthermore, the need for immersive learning environments has led to explorations of tools such as Virtual Reality, which have shown positive outcomes in mathematics instruction.[1] Therefore, gamification presents a promising strategy for enhancing learner involvement and academic achievement during disconnection.[2] The move to remote education also exposed significant disparities in technological access, pedagogical readiness, and learner engagement, raising concerns about the overall effectiveness of online mathematics delivery.[3] These challenges led many educators to reconsider their instructional methods to balance technological integration with accessibility and cognitive load. A growing body of scholarship has examined online teaching in mathematics during the pandemic, identifying critical factors such as teacher preparedness, digital infrastructure, and student motivation.[4] Inadequate preparation towards using digital platforms often intensifies the cognitive demands of teachers and learners.

Mailizar and Fan noted that issues around adaptability, institutional support, and curriculum flexibility were especially pronounced in mathematics education due to its reliance on structured tasks and immediate feedback.[5] This situation underscores the importance of assessing pedagogical and infrastructural variables that influence the success of online math teaching. While digital tools have shown promise in enhancing student understanding and participation, many schools lack the infrastructure and skilled personnel necessary for successful digital implementation.[6] This shortfall was particularly evident in underserved communities, where internet access and availability of devices were limited. Li emphasises that effective cognitive engagement in digital learning depends heavily on well-designed teaching strategies, which require teacher training, institutional backing, and clear policy direction.[7]

The move to online learning, prompted by recent educational disruptions, has highlighted considerable challenges in engaging students, particularly in mathematics instruction within the OR Tambo Coastal District, Eastern Cape, South Africa. Conventional teaching techniques often proved ineffective in remote settings, decreasing learner motivation and peer interaction among secondary school students. The transition disrupted established pedagogical dynamics, especially in subjects perceived as complex or abstract, such as mathematics. The absence of in-person learning environments further limited hands-on methods and spontaneous dialogue, which are both essential to learner engagement. Becuase of these setbacks, there is a growing demand for creative strategies that can reinvigorate student interest and participation in mathematics education. One such approach gaining traction is gamification, which integrates game-inspired elements into teaching and learning processes. Emerging research demonstrates that gamified instruction enhances learners' enthusiasm and comprehension in mathematics.[8] By framing mathematical tasks within interactive and goal-oriented

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1 James Hutson and Trent Olsen, "Virtual Reality and Art History: A Case Study of Digital Humanities and Immersive Learning Environments," *Journal of Higher Education Theory and Practice* 22, no. 2 (2022).

2 Joseph Mesuwini et al., "Work-Integrated Learning as a Pedagogical Tool to Integrate Theory and Practice for TVET Graduates," 2024, 117–41, https://doi.org/10.1007/978-3-031-58206-6_7.

3 Alex Ntsiful, Michael Adu Kwarteng, and Henry Egbezien Inegbedion, "How Health-Related Messaging Increase Intentions to Download and Use Mobile Contact (COVID-19) Tracing Apps: Preliminary Findings," *Cogent Social Sciences* 8, no. 1 (December 31, 2022), https://doi.org/10.1080/23311886.2022.2035912.

4 Ramona Maile Cutri, Juanjo Mena, and Erin Feinauer Whiting, "Faculty Readiness for Online Crisis Teaching: Transitioning to Online Teaching during the COVID-19 Pandemic," *European Journal of Teacher Education* 43, no. 4 (August 7, 2020): 523–41, https://doi.org/10.1080/02619768.2020.1815702.

5 Mailizar Mailizar and Lianghuo Fan, "Examining Indonesian Secondary School Mathematics Teachers' Instructional Practice in the Integration of Technology," *Universal Journal of Educational Research* 8, no. 10 (October 2020): 4692–99, https://doi.org/10.13189/ujer.2020.081038.

6 Jerome Amedu and Karen F Hollebrands, "Teachers' Perceptions of Using Technology to Teach Mathematics during COVID-19 Remote Learning," *Redimat* 11, no. 1 (2022): 71–85.

7 Mao Li, "Assessing Chinese Primary Mathematics Teachers' Self-Efficacy for Technology Integration: Development and Validation of a Multifaceted Scale," *Asian Journal for Mathematics Education* 3, no. 2 (June 22, 2024): 231–53, https://doi.org/10.1177/27527263241254496.

8 Chein-Hui Lee, Evelyn Saputri, and Min-Chi Chiu, "Application of Digital Gamification Systems in Intelligent Automated Learning," in *International Conference on Kansei Engineering & Emotion Research* (Springer, 2024), 177–88; Maryana Maryana, Chandra Halim, and Hanifatul Rahmi, "The Impact of Gamification on Student Engagement and Learning Outcomes in Mathematics Education," *International Journal of Business, Law, and Education* 5, no. 2 (June 11, 2024): 1697–1608,

activities, gamification repositions mathematics as a subject that can be approached with curiosity rather than apprehension. Furthermore, studies indicate that such strategies bolster internal motivation, increase attendance, and promote greater classroom participation, factors critical when rebuilding engagement after disrupted schooling.[9]

Nonetheless, integrating gamification into online or hybrid instruction is not without barriers. Many teachers face limited access to digital tools, insufficient training in technology-enhanced pedagogy, and the lack of adaptable instructional frameworks. These limitations hinder efforts to foster inclusive and effective mathematics learning in remote environments. The success of such innovations largely depends on the availability of institutional support, targeted teacher development, and infrastructural readiness. Therefore, it is essential to explore how gamification can be effectively deployed to rekindle student interest in mathematics while addressing digital equity and pedagogical preparedness.

The pandemic in South Africa further exacerbated educational inequalities, especially in rural and township schools, where digital learning resources were scarce. Evidence suggests that learners in under-resourced institutions continue to trail their counterparts in more affluent schools by several academic years, a gap that widened under remote learning conditions.[10] The rapid transition to digital platforms brought to light gaps in teachers' digital competencies, inadequate support systems, and widespread disparities in access to online tools by learners. Remuzzi and Remuzzi argue that addressing these systemic imbalances demands urgent policy reforms to ensure equitable access to quality mathematics education.[11] This study investigates how gamification can serve as a re-engagement mechanism for learners in mathematics following online learning disruptions in South African schools. It explores the relationships among teaching flexibility, technological infrastructure, and social inequality, aiming to offer evidence-based recommendations for improving digital mathematics education. This study seeks to identify the key instructional and infrastructural enablers of gamification in mathematics education, aiming to develop sustainable models that enhance learning outcomes post-disruption. Aligning student engagement theories with game-based instructional design offers a robust framework for evaluating and applying such approaches.[12] In addition, collaborative learning opportunities fostered in gamified environments can help demystify complex mathematical ideas through peer-to-peer dialogue and shared problem-solving experiences.[13] The findings contribute to ongoing debates about fairness in digital education, focusing on the structural barriers that hindered effective mathematics teaching during the pandemic, and aim to inform future strategies for building a more resilient and equitable education system in South Africa.The following questions underlie the study:

- How does the integration of gamification in mathematics education impact student engagement and motivation after online learning disruptions?
- What specific gamification strategies are most effective in improving students' mathematical problem-solving skills in a post-online learning environment?
- How do students with diverse learning needs respond to gamified mathematics education

https://doi.org/10.56442/ijble.v5i2.682; Carlos J. Hellín et al., "Enhancing Student Motivation and Engagement through a Gamified Learning Environment," *Sustainability* 15, no. 19 (September 24, 2023): 14119, https://doi.org/10.3390/su151914119; Errol Scott Rivera and Claire Louise Palmer Garden, "Gamification for Student Engagement: A Framework," *Journal of Further and Higher Education* 45, no. 7 (August 9, 2021): 999–1012, https://doi.org/10.1080/0309877X.2021.1875201.

[9] Yongzhong Yang et al., "Exploring the Impact of Gamified Elements on College Students' Learning in Virtual Learning Communities," *Kybernetes* 54, no. 9 (2025): 5133–57; Noizzie Tah Jutin and Siti Mistima Binti Maat, "The Effectiveness of Gamification in Teaching and Learning Mathematics: A Systematic," n.d.;Tareq Hussein et al., "Short-Term and Long-Term COVID-19 Pandemic Forecasting Revisited with the Emergence of OMICRON Variant in Jordan," *Vaccines* 10, no. 4 (April 7, 2022): 569, https://doi.org/10.3390/vaccines10040569.

[10] Pushkar Dubey and Deepak Pandey, "Distance Learning in Higher Education during Pandemic: Challenges and Opportunities," *The International Journal of Indian Psychology* 8, no. 2 (2020): 43–46.

[11] Andrea Remuzzi and Giuseppe Remuzzi, "COVID-19 and Italy: What Next?," *The Lancet* 395, no. 10231 (April 2020): 1225–28, https://doi.org/10.1016/S0140-6736(20)30627-9.

[12] Rivera and Garden, "Gamification for Student Engagement: A Framework."

[13] Harin Pratiwi, Daud K Walanda, and Nurasyah Dewi Napitupulu, "Development of LKPD on Project Based Learning to Improve Science Process Skills and Collaboration Skills for Junior High School Students," *International Journal of Education, Humaniora, and Social Studies*, 2024.

compared to traditional teaching methods following periods of disrupted learning?

LITERATURE REVIEW

The transition to online mathematics education, accelerated by the COVID-19 pandemic, has sparked considerable academic interest regarding its efficacy, obstacles, and future implications. The abrupt move from traditional classrooms to digital platforms revealed significant inequalities in access to technology, teaching flexibility, and learner participation. This section reviews current literature to highlight the primary elements shaping the effectiveness of remote mathematics instruction, with a particular focus on digital integration, pedagogical strategies, and systemic support. Research highlights that competency of educators largely influences effective online mathematics teaching using digital tools, the availability of technological infrastructure, and students' capacity to navigate remote learning environments.[14] Although digital tools have the potential to make mathematics more engaging and understandable, their success often hinges on teachers' confidence and competence in using them effectively.[15] In South Africa, the slow uptake of digital teaching practices in mathematics has frequently been linked to insufficient training opportunities and a lack of sustained institutional support.

Overview of the impact of online learning disruptions on student engagement in mathematics

Periods of disruption have compelled educational systems to rely heavily on online instruction, which has reshaped how students interact with mathematical content. The unexpected move from traditional classrooms presented several barriers, especially in sustaining student interest and fostering meaningful engagement with abstract concepts. Many learners reported a loss of connection with both peers and content, contributing to reduced motivation in tackling mathematics. As a result of these challenges, educators have turned to creative pedagogical solutions such as gamification. Tools like Nearpod introduce game-based features that promote attention, peer interaction, and active involvement—key elements supporting mathematical learning.[16] Evidence suggests that incorporating game-like activities in digital lessons boosts learner participation and accommodates individual learning preferences, leading to improved outcomes and more constructive attitudes toward the subject.[17]

The Concept of Gamification in Education and Practical Strategies to Improve Mathematical Problem-Solving Skills

Gamification in education refers to integrating game design principles and elements into learning environments to enhance student engagement and motivation. Teachers can transform traditional learning experiences into more interactive and enjoyable ones by applying these principles in educational contexts, particularly in mathematics.

Motivation and Engagement

Gamification, incorporating game elements into educational contexts, has enhanced student motivation and engagement. Features such as points, badges, and leaderboards offer learners visible performance indicators, encouraging effort and persistence through extrinsic motivation.[18] These mechanics not only serve as immediate rewards but also act as scaffolds that support learners' progression. For instance, badges and point systems acknowledge milestones, while leaderboards introduce healthy competition

[14] Alan C.K. Cheung and Robert E. Slavin, "The Effectiveness of Educational Technology Applications for Enhancing Mathematics Achievement in K-12 Classrooms: A Meta-Analysis," *Educational Research Review* 9 (June 2013): 88–113, https://doi.org/10.1016/j.edurev.2013.01.001; Nicholas Mlotshwa and Agnes Chigona, "Using Moodle to Enhance Mathematics Learning in Grade 10 Classrooms in South Africa," in *ELearn: World Conference on EdTech* (Association for the Advancement of Computing in Education (AACE), 2018), 429–38.

[15] D. H. Solis et al., " Perceptions and Needs of South African Mathematics Teachers Concerning Their Use of Technology for Instruction," *South African Journal of Education* 35, no. 4 (2015): 1–13.

[16] Nur Fauziyah and Raden Roro Martiningsih, "Effectiveness of Mathematics Learning Using the Google Sites Application at Junior High School," *JTAM (Jurnal Teori Dan Aplikasi Matematika)* 9, no. 1 (2025): 297–313.

[17] Angel Joie G Feleo, Jowenie A Mangarin, and Mary Ann N Cahayon, "Perceptions of Mathematics Student Teachers in the Implementation of Gamification in Secondary School at Nasugbu, Batangas," 2024.

[18] Ika Puspitasari and Shokhibul Arifin, "Implementation of Gamification on Learning Motivation: A Meta-Analysis Study," *International Journal of Progressive Sciences and Technologies* 40, no. 1 (2023): 356.

that can further increase participation.[19] Empirical research has consistently supported the efficacy of gamification in improving both learner engagement and academic outcomes. Meta-analyses and controlled studies report that gamified instruction increases situational interest and achievement, outperforming traditional teaching methods.[20] Furthermore, gamified classrooms foster student autonomy and self-regulation, creating more interactive and learner-centred environments.[21] Alsadoon highlights that these environments result in statistically significant gains in motivation and participation.[22]

The implementation of gamification has been effective across a variety of disciplines. In computer science education, game elements such as digital rewards and rankings have improved learner engagement and enhanced problem-solving performance.[23] In nursing education, gamified modules have addressed motivation and retention issues, particularly vital in high-attrition programs.[24] Similarly, gamification has helped create more immersive and satisfying learning experiences in language education, reducing dropout rates and promoting learner persistence.[25] Beyond extrinsic motivators, gamification can develop intrinsic motivation through meaningful and intellectually engaging challenges. This approach, called deep gamification, encourages sustained interest and cognitive engagement with the subject matter.[26] Although short-term effects such as increased participation are observable, future investigations are needed to understand how gamification contributes to learners' intrinsic reasoning, creativity, and independent learning capabilities.[27]

Immediate Feedback

Gamified learning environments often incorporate mechanisms that deliver real-time responses, allowing students to recognise errors and promptly refine their approaches. This timely feedback is a core element of effective gamification strategies in mathematics education, as it does not only sustains the interest of learners but also deepens their conceptual understanding. A variety of scholarly works reinforce this claim. For instance, Lister discusses how elements like points, digital badges, and ranking systems contribute both to student motivation and the provision of immediate performance-related feedback, which encourages consistent engagement and iterative improvement.[28]

Real-time responses enable learners to pinpoint misunderstandings and recalibrate their learning strategies, resulting in more personalised and adaptive learning experiences. García-Hernández and Ramírez support this notion by indicating that instant feedback during gamified tasks enhances

[19] Risna Oktaviati and Adam Amril Jaharadak, "The Impact of Using Gamification in Learning Computer Science for Students in University," *International Journal of Engineering & Technology* 7, no. 4.11 (2018): 121–25.

[20] Puspitasari and Arifin, "Implementation of Gamification on Learning Motivation: A Meta-Analysis Study"; Eddy Triswanto Setyoadi and Syaad Patmanthara, "Students' Goal Orientation and Gamification in Learning for Academic Performance: A Systematic Literature Review," *Research and Development Education (RaDEn)* 4, no. 1 (2024): 390–403.

[21] Lorena Jaramillo-Mediavilla et al., "Impact of Gamification on Motivation and Academic Performance: A Systematic Review," *Education Sciences* 14, no. 6 (June 13, 2024): 639, https://doi.org/10.3390/educsci14060639.

[22] Hamadah Alsadoon, "The Impact of Gamification on Student Motivation and Engagement: An Empirical Study," *Dirasat: Educational Sciences* 50, no. 2 (June 19, 2023): 386–96, https://doi.org/10.35516/edu.v50i2.255.

[23] Alberto Ferriz-Valero et al., "Gamification in Physical Education: Evaluation of Impact on Motivation and Academic Performance within Higher Education," *International Journal of Environmental Research and Public Health* 17, no. 12 (June 21, 2020): 4465, https://doi.org/10.3390/ijerph17124465.

[24] Laura A. Killam et al., "Virtual Screen-Based Clinical Simulation: An Integrative Review of Student Experiences," *Teaching and Learning in Nursing* 19, no. 2 (April 2024): e359–68, https://doi.org/10.1016/j.teln.2023.12.017.

[25] Tanya Elizabeth Preciado Asanza et al., "Gamification as a Didactic Motivator in Low-Resource Public English as a Foreign Language (EFL) Classrooms in Ecuador," *Ciencia Latina Revista Científica Multidisciplinar* 8, no. 2 (May 10, 2024): 5391–5402, https://doi.org/10.37811/cl_rcm.v8i2.10951.

[26] Javier del Olmo-Muñoz et al., "Intelligent Tutoring Systems for Word Problem Solving in COVID-19 Days: Could They Have Been (Part of) the Solution?," *ZDM – Mathematics Education* 55, no. 1 (February 22, 2023): 35–48, https://doi.org/10.1007/s11858-022-01396-w; Nur Asitah, Imam Suyitno, and Toto Nusantara, "PGSD Students' Perspectives on Gamification Learning in Indonesian Language Courses," *Jurnal Pemikiran Dan Pengembangan Sekolah Dasar (JP2SD)* 13, no. 1 (2025).

[27] del Olmo-Muñoz et al., "Intelligent Tutoring Systems for Word Problem Solving in COVID-19 Days: Could They Have Been (Part of) the Solution?"

[28] Genevive LeBaron and Jane Lister, "Benchmarking Global Supply Chains: The Power of the 'Ethical Audit' Regime," *Review of International Studies* 41, no. 5 (December 25, 2015): 905–24, https://doi.org/10.1017/S0260210515000388.

students' active participation and comprehension.[29] Similarly, Maryana et al. note that game-based environments promote regular practice and cooperative learning, where rapid feedback mechanisms help clarify abstract mathematical ideas.[30] Research by Jutin and Maat further shows that continuous feedback boosts learner motivation and fosters a more inviting and interactive classroom atmosphere, particularly in disciplines such as mathematics, which are often viewed as challenging.[31] In alignment with this, Liu underscores the role of prompt feedback in maintaining students' attention and drive, supporting sustained academic effort.[32] Vankúš adds that feedback delivered in the moment promotes a growth-oriented mindset, enabling learners to interpret setbacks as learning opportunities rather than failures, which can also mitigate anxiety associated with math performance.[33] Finally, integrating digital tools within gamified teaching practices significantly enhances the feedback loop. Jutin and Maat argue that technology enables more dynamic and tailored interactions.[34] Lopes et al. highlight that adaptive platforms allow for feedback customised to individual learning profiles, further supporting engagement and mastery of content.[35]

Collaboration and Competition

Embedding cooperative and competitive dynamics within educational environments can greatly enrich peer interaction and community engagement. These elements are especially beneficial in contexts where building a sense of belonging and mutual academic support is essential. By blending competition with teamwork, educators can promote deeper learning and foster a sense of shared purpose among students. Collaborative practices are instrumental in creating a favourable educational climate. For example, professional learning communities rely on mutual respect, joint accountability, and shared pedagogical strategies to drive innovation and continuous improvement among educators.[36] When students engage in collaborative tasks, they gain motivation and develop essential skills such as critical analysis, independence, and effective communication.[37] The social constructivist perspective suggests that knowledge is best constructed through social engagement and group effort, encouraging learners to support one another and take joint responsibility for academic success.[38] This interaction-driven learning process strengthens conceptual understanding and retention, as students actively exchange insights.[39] Moreover, such environments help learners become confident in sharing perspectives, which enhances their sense of agency and participation.[40]

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[29] Abel García-González and María Soledad Ramírez-Montoya, "Social Entrepreneurship Education: Changemaker Training at the University," *Higher Education, Skills and Work-Based Learning* 11, no. 5 (October 19, 2021): 1236–51, https://doi.org/10.1108/HESWBL-01-2021-0009.

[30] Maryana, Halim, and Rahmi, "The Impact of Gamification on Student Engagement and Learning Outcomes in Mathematics Education."

[31] Noizzie Tah Jutin and Siti Mistima Binti Maat, "The Effectiveness of Gamification in Teaching and Learning Mathematics: A Systematic Literature Review," *International Journal of Academic Research in Progressive Education and Development* 13, no. 1 (February 9, 2024), https://doi.org/10.6007/IJARPED/v13-i1/20703.

[32] Pengfei Liu et al., "Pre-Train, Prompt, and Predict: A Systematic Survey of Prompting Methods in Natural Language Processing," *ACM Computing Surveys* 55, no. 9 (September 30, 2023): 1–35, https://doi.org/10.1145/3560815.

[33] Peter Vankúš, "Game-Based Learning and Gamification Technologies in the Preparation of Future Mathematics Teachers," *International Journal of Interactive Mobile Technologies (IJIM)* 17, no. 11 (June 7, 2023): 53–67, https://doi.org/10.3991/ijim.v17i11.39227.

[34] Tah Jutin and Binti Maat, "The Effectiveness of Gamification in Teaching and Learning Mathematics: A Systematic Literature Review."

[35] M. Beatriz S. Lopes, "The 2017 World Health Organization Classification of Tumors of the Pituitary Gland: A Summary," *Acta Neuropathologica* 134, no. 4 (October 18, 2017): 521–35, https://doi.org/10.1007/s00401-017-1769-8.

[36] Paula Lahann and Diana V Lambdin, "Collaborative Learning in Mathematics Education," in *Encyclopedia of Mathematics Education* (Springer, 2014), 75–76.

[37] Cato Dambre et al., "Working toward a Transdisciplinary Approach to Teaching and Learning Planetary Health–A Collective Reflection," *Frontiers in Public Health* 10 (2022): 1039736; Miftachul Amri et al., "Assessing the Influence of Peer Collaboration, Classroom Management, and Assessment Practices on Student Motivation in Secondary Education," *International Journal of Business, Law, and Education* 5, no. 2 (June 2, 2024), https://doi.org/10.56442/ijble.v5i2.660.

[38] Amri et al., "Assessing the Influence of Peer Collaboration, Classroom Management, and Assessment Practices on Student Motivation in Secondary Education."

[39] E. Alkhawaldeh, "Examining the Integration of Project-Based Learning and Technology Tools in K-12 Classrooms " (King Khalid University, Saudi Arabia, 2023).

[40] K. S. Brundage, " The Experience of Academic Library Deans and Directors during the COVID-19 Pandemic: An Interpretive Phenomenological Analysis " (Northeastern University, 2022).

Simultaneously, integrating competitive challenges within this collaborative setting can catalyse self-driven learning and heightened engagement. Healthy competition can inspire students to strive for excellence while drawing knowledge and strategies from their peers, resulting in a dynamic and interactive classroom culture.[41] When learners participate in peer mentoring or challenge-based activities, their drive to succeed is amplified, and they benefit from giving and receiving guidance.[42] This dual framework allows for meaningful exchanges where explaining concepts to others reinforces one's mastery.[43] When thoughtfully managed, competition and collaboration complement one another, offering diverse opportunities for engagement and comprehension, particularly in dealing with complex subject matter.[44] These strategies holistically foster a vibrant educational setting where learners form supportive peer networks, engage in dialogue, and collaboratively tackle academic challenges.[45] Such an environment bolsters performance and equips students with vital interpersonal and leadership skills necessary for success beyond the classroom.[46] Hence, embedding cooperative and competitive structures into educational practice is a strategic approach to building inclusive, empowering learning communities.

The Effectiveness of Gamified Mathematics Instruction for Students with Diverse Learning Needs in Post-Disruption Educational Settings

The adoption of gamified mathematics instruction has shown considerable promise in supporting learners with varied educational needs, particularly in the wake of learning disruptions. Game-based approaches yield more positive outcomes regarding learner engagement and performance than conventional teaching strategies. Researchers have noted that incorporating game elements into mathematics lessons can foster motivation and boost learners' confidence, which are essential for academic success, especially for those who find traditional approaches challenging.[47] These interactive methods increase enjoyment and deepen students' conceptual understanding by encouraging active participation. In one study, learners showed marked improvement in arithmetic and rational number tasks after engaging with math games. This suggests these tools are more than just supplementary, they can outperform standard practices in some contexts. Yu et al. further argue that learning models prioritising student interest and active participation can significantly sharpen computational proficiency and promote effective problem-solving.[48]

Given that students differ in how they absorb and process information, gamified learning offers flexible, learner-centred experiences that traditional methods often lack. Lin emphasises that when educational activities are tailored primarily through personalised gaming features to meet individual needs, learner engagement and comprehension can rise substantially.[49] Similarly, Huang highlights how interactive learning formats can nurture skills such as mathematical modelling, which benefits from adaptable teaching strategies.[50] In contrast, traditional methods—particularly in post-pandemic

[41] Sarah E Hill, Danielle J DelPriore, and Phillip W Vaughan, "The Cognitive Consequences of Envy: Attention, Memory, and Self-Regulatory Depletion.," *Journal of Personality and Social Psychology* 101, no. 4 (2011): 653.

[42] Gayathripriya Narayanan, "Effect of Peer Assisted Learning on Improving Psychomotor Skills, Self-Confidence and Attitude among Second Year Nursing Students," in *2021 Sustainable Leadership and Academic Excellence International Conference (SLAE)* (IEEE, 2021), 1–7, https://doi.org/10.1109/SLAE54202.2021.9788094.

[43] S. Du and H. Tan, "Improving University Students' Classroom Learning Outcomes through Multi-Dimensional Enhancement Methods Based on the Knowledge-Attitude-Practice Model," *Frontiers in Educational Research* 7, no. 6 (2024), https://doi.org/10.25236/FER.2024.070605.

[44] Inge Bakkenes, Jan D. Vermunt, and Theo Wubbels, "Teacher Learning in the Context of Educational Innovation: Learning Activities and Learning Outcomes of Experienced Teachers," *Learning and Instruction* 20, no. 6 (December 2010): 533–48, https://doi.org/10.1016/j.learninstruc.2009.09.001.

[45] Amel Shoaib, "Student Perceptions of Teacher Immediacy, Credibility, and Love of Pedagogy in Enhancing Learner Engagement and Motivation in Higher EFL Education," *Journal of Language Teaching* 3, no. 10 (October 18, 2023): 1–13, https://doi.org/10.54475/jlt.2023.024.

[46] Solis et al., " Perceptions and Needs of South African Mathematics Teachers Concerning Their Use of Technology for Instruction."

[47] Nelson David Guerra Castillo, "La Gamificación Como Estrategia Innovadora Para El Fomento Del Aprendizaje de Las Matemáticas En Los Estudiantes de Grado Tercero de La Institución Educativa de Puerto Rico," 2024.

[48] Yang et al., "Exploring the Impact of Gamified Elements on College Students' Learning in Virtual Learning Communities."

[49] Zhicheng Lin, "Why and How to Embrace AI Such as ChatGPT in Your Academic Life," *PsyArXiv*, February 5, 2023, https://doi.org/10.31234/osf.io/sdx3j.

[50] Xiaowei Huang, "Understanding Bourdieu - Cultural Capital and Habitus," *Review of European Studies* 11, no. 3 (August 7, 2019): 45, https://doi.org/10.5539/res.v11n3p45.

environments, have drawn critique for their limited ability to hold students' attention. The static nature of these methods can hinder progress for learners with diverse needs, as they often lack the interactivity required for meaningful engagement.[51] The recent reliance on digital and hybrid models during COVID-19 has highlighted the necessity of inventive instructional approaches. Amoah suggests that well-designed blended learning environments can better accommodate learner diversity and support improved academic results.[52]

Digital Technologies and Online Mathematics Instruction

The rise of digital platforms has significantly transformed teaching practices, especially in mathematics, where visual understanding is essential for mastering abstract concepts. According to Li (2024), the success of online mathematics education is closely tied to interactive digital tools, such as virtual simulations and dynamic software, which promote active learner involvement. These technologies offer pedagogical benefits, including personalised feedback and adaptive systems that support students' problem-solving skills while reducing cognitive strain.[53] Nevertheless, the practical application of such tools relies heavily on the availability of robust technological infrastructure and teachers' competence in using digital pedagogies. Although digital education holds considerable promise, the rapid move to online learning during the COVID-19 crisis exposed widespread institutional limitations. Research shows that numerous schools were ill-equipped to support digital instruction due to inadequate resources.[54] In South Africa, socio-economic inequality has further deepened the digital divide, hindering many learners' access to quality online mathematics education. Mishra, Gupta, and Shree note that successful engagement in digital learning environments largely depends on students' consistent access to fast internet, appropriate devices, and relevant educational applications, resources that remain unevenly distributed between rural and urban areas.[55]

Pedagogical Adaptation and School Readiness

The success of teaching mathematics in virtual environments hinges on educators' capacity to reconfigure traditional strategies for digital delivery. According to recent findings, mathematics instruction demands ongoing support and real-time feedback, both of which can be limited in self-paced or asynchronous formats.[56] One significant barrier to effective technology use in teaching is educators' limited exposure to digital tools and the absence of systemic support structures.[57]

Furthermore, the degree of technological competence of teachers plays a critical role in determining how readily they adopt digital learning practices.[58] During periods of emergency remote instruction, those who had undergone training in digital teaching methods reported improved student

[51] Mahiswaran Selvanathan, Nur Atikah Mohamed Hussin, and Noor Alyani Nor Azazi, "Students Learning Experiences during COVID-19: Work from Home Period in Malaysian Higher Learning Institutions," *Teaching Public Administration* 41, no. 1 (March 6, 2023): 13–22, https://doi.org/10.1177/0144739420977900; Miftakul Andriani, Sunardi, and Nur Arifah Drajati, "Looking for a Fun Way to Learn English Vocabulary? Discover the Magic of Gamification with Digital Flashcards," *Voices of English Language Education Society* 8, no. 2 (August 26, 2024), https://doi.org/10.29408/veles.v8i2.26810.

[52] Emmanuel Amoah, "Gender and Other Significant Factors Causing Disparities in Senior High School Students' Mathematics Performance," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)* 15, no. 1 (January 16, 2024): 26–33, https://doi.org/10.61841/turcomat.v15i1.14020.

[53] Pablo Mayorga and Sue Pope, "Enriching Mathematics in the Primary Curriculum," 2019.

[54] Sri Ambarwati, Tri Astuti, and Salsabila Azzahra, "Determinan Nilai Perusahaan Sebelum Dan Pada Masa Pandemic Covid-19," *Business Economic, Communication, and Social Sciences (BECOSS) Journal* 3, no. 2 (May 31, 2021): 79–89, https://doi.org/10.21512/becossjournal.v3i2.7415; Duc Huy Ngo, "Exploring EFL Undergraduates' Views of the Impact Teachers Have on Their Online Learning Engagement during the COVID-19 Pandemic in Vietnam," *International Journal of TESOL & Education* 2, no. 3 (June 17, 2022): 75–95, https://doi.org/10.54855/ijte.22236.

[55] Lokanath Mishra, Tushar Gupta, and Abha Shree, "Online Teaching-Learning in Higher Education during Lockdown Period of COVID-19 Pandemic," *International Journal of Educational Research Open* 1 (2020): 100012, https://doi.org/10.1016/j.ijedro.2020.100012.

[56] Eabhnat Ní Fhloinn and Olivia Fitzmaurice, "Mathematics Lecturers' Views on the Student Experience of Emergency Remote Teaching Due to COVID-19," *Education Sciences* 12, no. 11 (November 4, 2022): 787, https://doi.org/10.3390/educsci12110787.

[57] Mailizar and Fan, "Examining Indonesian Secondary School Mathematics Teachers' Instructional Practice in the Integration of Technology."

[58] Yilun Du et al., "Improving Factuality and Reasoning in Language Models through Multiagent Debate," in *Forty-First International Conference on Machine Learning*, 2023.

interaction and more effective delivery.[59] The transition to online education has also highlighted the importance of curricula adapting to diverse student needs. Amedu and Hollebrands emphasise that online pedagogies must be flexible enough to accommodate varying learning styles.[60] However, traditional mathematics syllabi, which typically depend on step-by-step instruction and face-to-face teacher facilitation, created obstacles for learners used to in-person education.[61] As a result, scholars increasingly support blended learning models that combine live sessions with independent online work to improve understanding and learning outcomes.

THEORETICAL FRAMEWORK

This study draws its theoretical basis from Wenger's Community of Practice (CoP) framework, which highlights how individuals collaboratively build knowledge within social and professional groups.[62] The CoP perspective emphasises that learning occurs through active involvement, shared experiences, and participation in group practices. Applied to online mathematics education, this theory offers valuable insight into how teachers and students adjust their instructional strategies and use of digital tools to foster rich and interactive mathematical learning. Figure 1 below shows how the application of the Community of Practice theory applies to this study.

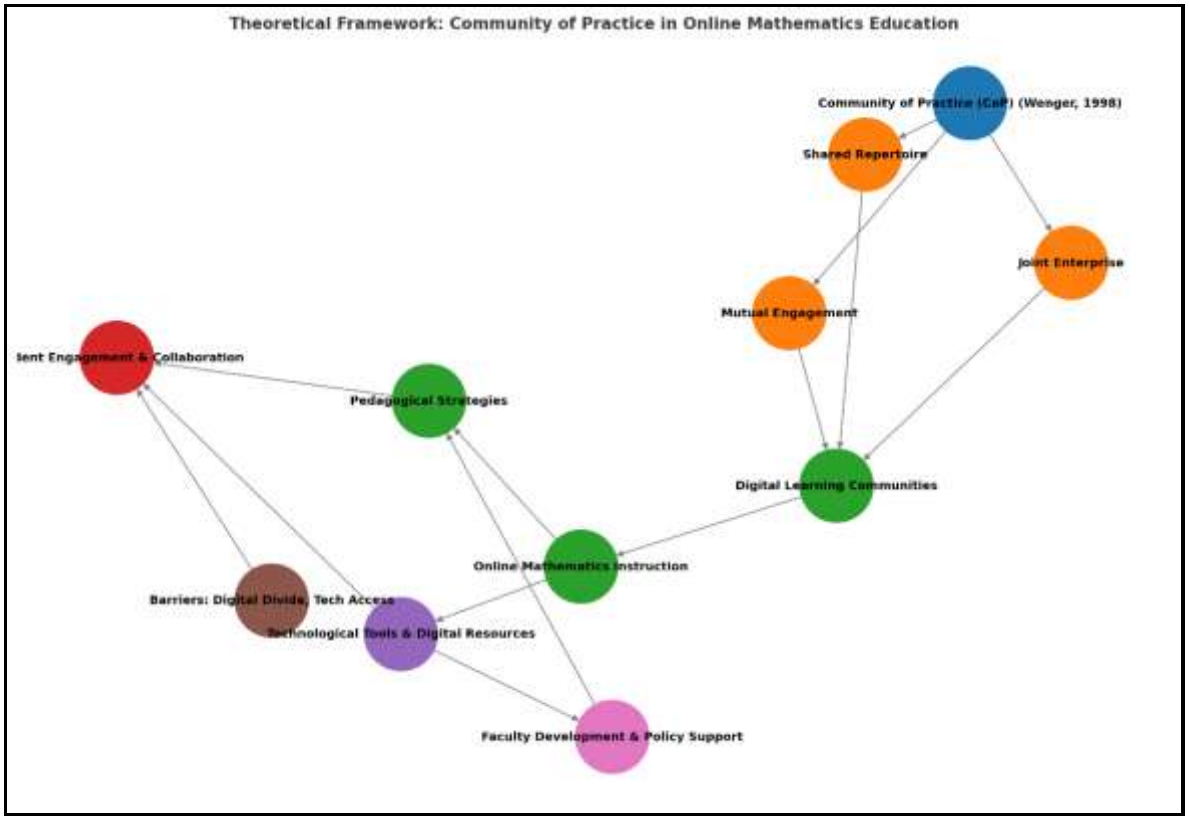

Figure 1: A graphical illustration of a community of practice in online Mathematics Education

Community of Practice and Digital Mathematics Instruction

Wenger's theory of communities of practice (CoP) identifies three key elements: joint enterprise, mutual engagement, and a shared repertoire.[63] These components are evident in digital mathematics education, in which educators and students form virtual communities supporting collaborative

[59] Zaenal Mustakim, Siti Fatimah, and Umi Mahmudah, "Students 'perception and Motivation on e-Learning during the COVID-19 Pandemic," *Online Education during the COVID-19 Pandemic: Issues, Benefits, Challenges, and Strategies* 59 (2021).
[60] Amedu and Hollebrands, "Teachers' Perceptions of Using Technology to Teach Mathematics during COVID-19 Remote Learning."
[61] Ivana Nedeljković and Dragana Rejman Petrović, "Student Satisfaction and Intention to Use E-Learning during the Covid-19 Pandemic," *The International Journal of Information and Learning Technology* 40, no. 3 (2023): 225–41.
[62] Etienne Wenger, "Communities of Practice: Learning as a Social System," *Systems Thinker* 9, no. 5 (1998): 2–3.
[63] Wenger, "Communities of Practice: Learning as a Social System."

knowledge construction through real-time and delayed communication. In teaching mathematics, where comprehension often develops through repeated practice and group problem-solving, the CoP model emphasises the importance of active and socially interactive learning environments.[64] The relevance of CoP in digital education has been confirmed by research indicating that online learning tends to be more impactful when learners view themselves as contributors within a collaborative knowledge network.[65] Nevertheless, the abrupt shift to remote teaching during the COVID-19 crisis disrupted established patterns of community building in education. Scholars have observed that a lack of purposeful interaction in online mathematics classes diminished learner participation and enthusiasm.[66] These findings highlight the critical need for pedagogical strategies that purposefully cultivate virtual communities of practice to enhance student engagement and foster cooperative learning.

Pedagogical Implications of CoP in Online Mathematics Education

Integrating digital tools into mathematics instruction necessitates re-conceptualising teaching methodologies to align with CoP principles. Traditionally, mathematics instruction has relied on direct, teacher-centred pedagogies with explicit problem demonstrations and scaffolded exercises. However, within online learning environments, students must assume greater autonomy in constructing mathematical knowledge, necessitating pedagogical strategies emphasising interactive engagement and collaborative problem-solving.[67] The research underscores that educators' ability to cultivate online communities of practice is a key determinant of instructional efficacy. Instructors who leverage digital platforms to facilitate real-time discussions, peer collaboration, and formative assessment create learning environments that closely mirror the interactive dynamics of face-to-face instruction.[68] Conversely, the absence of structured engagement mechanisms in virtual classrooms has been correlated with increased attrition rates and diminished academic performance.[69] This reinforces the necessity for faculty development programs to equip educators with the skills to implement CoP-aligned digital pedagogies.

Technological Integration and the Evolution of Learning Communities

While Wenger's CoP framework was initially conceptualised within the context of in-person professional learning communities, contemporary adaptations have extended its applicability to digital learning ecosystems.[70] The advent of digital collaboration tools, interactive mathematics software, and virtual discussion forums has expanded the modalities through which communities of practice can be established and sustained in online education.[71] Research suggests that platforms incorporating interactive whiteboards, AI-driven tutoring systems, and gamified learning modules enhance students' sense of belonging within digital learning communities, thereby improving engagement and learning outcomes.[72] Nonetheless, the digital divide remains a salient barrier to the equitable formation of online communities of practice. In underprivileged educational contexts, where access to digital devices and high-speed internet is limited, learners are often excluded from the participatory dimensions of online mathematics instruction.[73] vvThis underscores the necessity for policy interventions to mitigate

[64] Barbara Jaworski, "The Practice of (University) Mathematics Teaching: Mediational Inquiry in a Community of Practice or an Activity System," *CERME 6–WORKING GROUP 9*, 2010, 1585.
[65] Peggy A. Ertmer and Anne Ottenbreit-Leftwich, "Removing Obstacles to the Pedagogical Changes Required by Jonassen's Vision of Authentic Technology-Enabled Learning," *Computers & Education* 64 (May 2013): 175–82, https://doi.org/10.1016/j.compedu.2012.10.008.
[66] Ní Fhloinn and Fitzmaurice, "Mathematics Lecturers' Views on the Student Experience of Emergency Remote Teaching Due to COVID-19."
[67] Florence Martin and Doris U Bolliger, "Engagement Matters: Student Perceptions on the Importance of Engagement Strategies in the Online Learning Environment.," *Online Learning* 22, no. 1 (2018): 205–22.
[68] Ming Li and Zhonggen Yu, "Teachers' Satisfaction, Role, and Digital Literacy during the COVID-19 Pandemic," *Sustainability* 14, no. 3 (January 19, 2022): 1121, https://doi.org/10.3390/su14031121.
[69] Amedu and Hollebrands, "Teachers' Perceptions of Using Technology to Teach Mathematics during COVID-19 Remote Learning."
[70] Wenger, "Communities of Practice: Learning as a Social System."
[71] Mustakim, Fatimah, and Mahmudah, "Students 'perception and Motivation on e-Learning during the COVID-19 Pandemic."
[72] Du et al., "Improving Factuality and Reasoning in Language Models through Multiagent Debate."
[73] Mellony Graven, "Strengthening Maths Learning Dispositions through 'Math Clubs,'" *South African Journal of Childhood Education* 5, no. 3 (February 6, 2016), https://doi.org/10.4102/sajce.v5i3.342.

technological inequities and ensure all students can access the resources required to engage in CoP-driven online learning. The Community of Practice Theory offers a compelling framework for understanding online mathematics education's complexities, particularly in emergency remote teaching. By highlighting the social dimensions of learning, CoP underscores the importance of digital interaction, collaborative problem-solving, and participatory engagement in fostering effective online instructional environments. However, the extent to which CoP principles can be operationalised in virtual mathematics education is contingent upon educators' pedagogical adaptability, institutional support structures, and technological accessibility. This theoretical foundation informs the subsequent examination of empirical findings, offering a lens through which the study interrogates the effectiveness of online mathematics instruction in South Africa.

METHODOLOGY

Research Design

The study adopted a qualitative case study design situated within the interpretive paradigm, which emphasises subjective meaning-making and contextual understanding. This design enabled an in-depth exploration of how gamified mathematics education re-engaged learners after online learning disruptions in selected secondary schools within the OR Tambo Coastal District.

Study Population and Sample

The population comprised Grade ten (10) mathematics teachers and learners who had participated in gamified online mathematics learning. Using purposive sampling, fifteen participants were selected, five teachers and ten learners, based on their direct experience with digital mathematics instruction during the pandemic.

Data Collection

Data were gathered through semi-structured interviews to obtain rich, descriptive insights into participants' experiences. The interviews explored themes related to technological access, pedagogical adaptation, student engagement, and institutional support. All sessions were audio-recorded with the consent of the participants to ensure accurate transcription.

Data Analysis Procedure

Data were analysed using **thematic analysis**, following Creswell's inductive coding process.[74] Transcribed interviews were read repeatedly to identify recurring patterns and emergent themes, which were then categorised to reflect pedagogical, technological, and socio-cultural dimensions of gamified learning.

Ethical Considerations

Ethical clearance was obtained from the university's research ethics committee. Participants were fully informed about the study's purpose, and voluntary participation, anonymity, and confidentiality were ensured throughout. Written consent was obtained before data collection, and all information was handled in compliance with ethical research standards.

PRESENTATION OF RESULTS

Teachers' Views

Challenges of learning and teaching mathematics online

This section outlines the feedback from participants about four primary themes that emerged from the data analysis: using gamification to re-engage students in mathematics after online learning disruptions presented various obstacles, especially in rural regions. These challenges can be divided into technological, pedagogical, and socio-economic factors and particular difficulties.

[74] John W. Creswell, *Research Design: Quantitative, Qualitative and Mixed Methods Approaches*, 4th Editio (Thousand Oaks, California: Sage Publications, 2014).

Technological Challenges

During interviews, teachers were asked various questions about the challenges of learning and teaching mathematics using gamification. Different participants gave their responses to each question. A participant from another site responded, "In rural areas, there is a lack of internet connection ''Not all students have equal access to technology, creating barriers to participation." Another participant said, "Learning disruptions posed several challenges for teachers and learners who *did not have access to necessary devices like computers, tablets, or smartphones to participate in online learning."* The participant from a different site said, "*Frequent power outages due to load shedding and technical glitches disrupted the learning process, leading to loss of teaching time." Another challenge we faced post-COVID-19 was the lack of digital skills needed to use gamification strategies, learning platforms, and tools effectively",* she concluded. "Measuring student learning and progress in a gamified environment may not always be straightforward."

Pedagogical Challenges

With respect to the pedagogical challenges of using gamified mathematics instruction, teachers responded with the following:. The participant said, "Specific gamification strategies are most effective in improving students' mathematical problem-solving skills in a post-online learning environment. Engaging learners in mathematics can be challenging ''*Some students focus more on winning the game than learning the mathematical concepts."* Another participant's response indicated, "*It is difficult to engage my learners, and ensuring interactive participation in an online setting was difficult, especially for a subject like mathematics that often requires hands-on practice and immediate feedback."* Another participant from another site responded, "*Many students in post-disruption contexts face issues with access to devices and reliable internet, which hinders the implementation of online-based gamified learning.*"Another participant said, "*Teachers might struggle to collaborate effectively with colleagues, particularly in rural or under-resourced settings, where access to technology, knowledge, and collaborative platforms may be limited."*

Socio-Economic Challenges

Teachers were asked about how students with diverse learning needs respond to gamified mathematics instruction as compared to traditional teaching methods. Different responses came from other participants: *"Families in rural areas did not afford the costs associated with online learning, such as internet data plans and digital devices for their children."* Responses from participants were likely similar regarding challenges faced by teachers: *"Managing game mechanics while also processing math concepts can be overwhelming, particularly for students with attention difficulties or executive functioning challenges*." One participant responded, *"Some students struggle with multitasking within digital game environments."*

Learners'views

Analysis of responses by learners

The following is the discussion of the responses to questions posed by the researcher to the learners in five (5) different schools. A question to the learners regarding the challenges they face when using gamification in mathematics after online learning disruptions.

This statement is strengthened by the excerpt from an interview with one of the research participants. "*I came from low-resource backgrounds, which caused a lack of access to devices or a stable internet connection, limiting my ability to engage with gamified learning." (Student 1)*

Another student also pointed out that they faced problems while studying mathematics using online learning.

"*I think I understand mathematics better when using gamification. It was my first online learning, and I felt nervous and unfamiliar with operating." "A lack of familiarity with technology hinders participation and progress.'' (Student 2)*

"*The internet signal was unstable, and the study duration was unclear. I sometimes did not understand the mathematics content taught online, and asking the lecturer about the learning content was difficult.*

Another obstacle I felt was my eyes hurting since I had been staring at the laptop for a long time. Sometimes, I also felt dizzy. Furthermore, internet credit is also expensive, and I sometimes run out of internet credit to access the e-learning classes". (Student 3)

"*Most of us as learners did not have access to personal computers, tablets, or smartphones, which are essential for online learning." "Since I am living in rural areas, we often suffer from slow or unreliable internet connections, making it difficult to attend live classes, download materials, or access online resources." (Student 4)*

"*Since we are in rural areas, we have limited experience with digital tools, leading to difficulties in navigating online learning platforms and using educational software; the only platform better for us was WhatsApp." On another site, one participant said,* "*We have less exposure to digital tools, making it harder for us to engage with and benefit from gamified learning. (Student 5)*

"*There is often a lack of immediate technical support for troubleshooting issues with devices or internet connectivity." "Another challenge is that we progress too quickly without mastering fundamental concepts, while others may struggle to keep up."* Another participant's view is that "*schools in underfunded areas did not have the resources to implement gamified instruction effectively, leading to disparities in student experiences."(Student 6)*

DISCUSSION

Limited access to digital technologies remains a problem in educational discourse, particularly in virtual and gamified learning contexts. Students residing in remote or underserved regions often face difficulties such as unstable internet services and limited availability of devices, contributing to significant disparities in learner participation and engagement. One participant shared that, "In rural areas, internet connectivity is completely lacking." This reflects how these infrastructural gaps affect involvement. These inequalities are shaped by intersecting geographic and socio-economic factors, as research shows that learners from urban, well-resourced backgrounds are often better equipped for digital learning environments.[75] Similarly, others have noted how insufficient technological support and inadequate digital infrastructure hinder effective online learning.[76] These conditions highlight the need to use alternative learning spaces, such as community hubs, to support learners who lack personal access to technology.

Innovative and flexible teaching models tailored to rural contexts are essential to address these obstacles.[77] Teaching mathematics online adds further complications, as learners may focus on engaging with game-like features without fully understanding core mathematical principles. Gamified environments, while potentially motivating, risk shifting attention away from deep conceptual learning.[78] Mathematics education often requires higher levels of interaction and real-time feedback, which are difficult to achieve in digital-only formats.[79] The lack of immediacy and peer collaboration in online platforms weakens the learning experience, particularly in mathematics.[80]

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[75] Lois Gwyn Peter and Adelina Asmawi, "Online Remote ESL Education Challenges, Opportunities and Readiness among High School Students during School Closure," *JOALL (Journal of Applied Linguistics and Literature)* 8, no. 2 (June 9, 2023): 281–302, https://doi.org/10.33369/joall.v8i2.26821.

[76] Aziz Naciri et al., "E-Learning in Health Professions Education during the COVID-19 Pandemic: A Systematic Review," *Journal of Educational Evaluation for Health Professions* 18 (October 29, 2021): 27, https://doi.org/10.3352/jeehp.2021.18.27; Finny Redjeki and Azhar Affandi, "Utilization of Digital Marketing for MSME Players as Value Creation for Customers during the COVID-19 Pandemic," *International Journal of Science and Society* 3, no. 1 (2021): 40–55.

[77] Ence Surahman and Ujang Nendra Pratama, "Online Observation Protocol to Supervise Online Learning and Its Sample Report," in *7th International Conference on Education and Technology (ICET 2021)* (Atlantis Press, 2021), 6–12.

[78] Robin Göller, Lara Gildehaus, and Juulia Lahdenperä, "Students' Self-Regulated Learning of University Mathematics in Different Learning Environments," *International Journal of Mathematical Education in Science and Technology*, June 6, 2024, 1–24, https://doi.org/10.1080/0020739X.2024.2341035.

[79] Eabhnat Ní Fhloinn and Olivia Fitzmaurice, "Challenges and Opportunities: Experiences of Mathematics Lecturers Engaged in Emergency Remote Teaching during the COVID-19 Pandemic," *Mathematics* 9, no. 18 (September 18, 2021): 2303, https://doi.org/10.3390/math9182303; Seema Joshi, "Alumni Engagement in Higher Education Sector: What Does the Literature Tell Us," *Department of Economics (UGC CAS Phase II) Sardar Patel University, Vallabh Vidyanagar* 17 (2022): 55–64.

[80] Farzad Radmehr and Simon Goodchild, "Switching to Fully Online Teaching and Learning of Mathematics: The Case of Norwegian Mathematics Lecturers and University Students During the Covid-19 Pandemic," *International Journal of Research in Undergraduate Mathematics Education* 8, no. 3 (October 18, 2022): 581–611, https://doi.org/10.1007/s40753-021-00162-9.

Disruptions to traditional education have revealed stark inequalities in digital access, severely limiting the impact of online gamified strategies.[81] Students in disadvantaged regions often report limited device availability and connectivity, reducing their ability to participate fully in remote math instruction.[82] This digital divide exacerbates educational imbalances and diminishes educators' capacity to create inclusive, real-time online learning experiences. Infrastructural deficits and financial constraints mean that many rural families cannot provide learners with the necessary tools for digital participation. Consequently, teachers working in these areas face pedagogical and logistical challenges, including insufficient training, which contributes to learning gaps between rural and urban students.[83] South African studies further confirm that a lack of training and resource provision impairs student involvement and learning outcomes.[84]

These disparities underscore the importance of adapting teaching strategies to rural realities. Scholars recommend context-specific support mechanisms and infrastructure development to enable equitable online learning.[85] Tailoring digital solutions to match the needs of rural learners—in terms of cognitive engagement and technological capacity—can reduce barriers to participation and promote inclusivity.[86] Integrating gamified learning in mathematics post-COVID-19 has proven particularly demanding for under-resourced students, due to insufficient access, limited connectivity, and unfamiliarity with digital tools. Students expressed concern about their limited exposure to online platforms and the associated negative impact on their learning. One noted, "Due to financial and technical limitations, I couldn't fully engage with the gamified content."[87] These personal accounts mirror findings that technological constraints are more acute in rural environments, deepening educational inequality.[88] Unstable internet services also affect academic comprehension, with one learner reporting difficulty understanding math lessons due to frequent disconnections.[89] Additionally, high internet costs pose economic challenges for many families. Beyond technical and economic issues, some learners lack the skills needed to confidently use digital learning platforms, making engagement with gamified approaches even more difficult.[90]

RECOMMENDATIONS

Instructors in online education must adopt diverse and engaging pedagogical strategies to foster student participation. Figure 2 below provides a summary of the key recommendations for improving online learning:

[81] Jennifer L. Ruef and Reid Shepard, "Relational Equity: Adapting an Elementary Mathematics Teaching Methods Course to Online Contexts," *International Electronic Journal of Mathematics Education* 17, no. 4 (July 12, 2022): em0699, https://doi.org/10.29333/iejme/12224.

[82] Neliswa Gqoli and Israel Kariyana, "Online Teaching and Learning of Mathematics in Higher Education: Post-Covid 19 Lecturer Perspectives," *E-Journal of Humanities, Arts and Social Sciences* 4, no. 12 (2023): 116–25.

[83] Bekithemba Dube, "Rural Online Learning in the Context of COVID 19 in South Africa: Evoking an Inclusive Education Approach," *Multidisciplinary Journal of Educational Research* 10, no. 2 (June 15, 2020): 135, https://doi.org/10.17583/remie.2020.5607.

[84] Newlin Marongwe and Rufaro Garidzirai, "Together but Not Together: Challenges of Remote Learning for Students Amid the COVID-19 Pandemic in Rural South African Universities.," *Research in Social Sciences and Technology* 6, no. 3 (2021): 213–26.

[85] David Arsen et al., "Rural Communities Need Better State Education Policies," *Phi Delta Kappan* 103, no. 4 (December 6, 2021): 8–13, https://doi.org/10.1177/00317217211065820.

[86] M Piekut and J Rybaltowicz, "The Role of Information and Communication Technologies in Rural Development/Rola Technologii Informacyjno-Komunikacyjnych w Rozwoju Obszarów Wiejskich," *Zagadnienia Ekonomiki Rolnej/Problems of Agricultural Economics* 378, no. 1 (2024): 69–92.

[87] Erik Kormos and Kendra Wisdom, "Rural Schools and the Digital Divide: Technology in the Learning Experience," *Theory & Practice in Rural Education* 11, no. 1 (2021): 25–39.

[88] Reham Omar et al., "Chatgpt versus Traditional Question Answering for Knowledge Graphs: Current Status and Future Directions towards Knowledge Graph Chatbots," *ArXiv Preprint ArXiv:2302.06466*, 2023.

[89] Carolina Kiong and Rozita Radhiah Said, "The Development of Ideas for Writing the Introduction of An Argumentative Essay by Using The 'Idea-Reality-Action-Now' (IRAN) Technique among Non-Native Speakers in Sarikei District, Sarawak," *International Journal of Academic Research in Progressive Education and Development* 12, no. 2 (May 16, 2023), https://doi.org/10.6007/IJARPED/v12-i2/17253.

[90] Omar et al., "Chatgpt versus Traditional Question Answering for Knowledge Graphs: Current Status and Future Directions towards Knowledge Graph Chatbots."

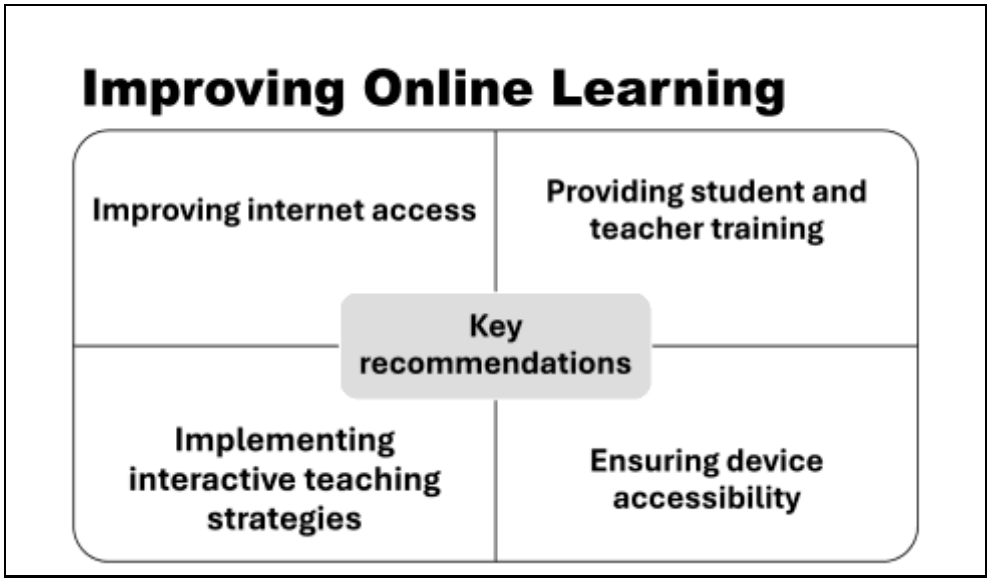

Figure 2: Illustration of the key recommendations for improving online learning

Creating engaging online lessons that actively involve learners is essential for maintaining motivation in virtual settings. Successful digital learning environments depend on consistent access to appropriate technology, such as laptops, smartphones, or tablets, and stable internet connectivity. Equally important is the digital literacy of both educators and students, which can be enhanced through structured capacity-building programs and ongoing technical assistance. Teaching practices should be redesigned to fit the demands of online education, using interactive techniques, such as live discussions, multimedia resources, and educational games instead of conventional lecture formats. To boost learning outcomes, curriculum content should be adapted for digital delivery by simplifying complex material and incorporating visual or auditory aids that aid comprehension. Thehome circumstances of students also significantly influence their online learning experience. Those who benefit from quiet study areas, familial encouragement, and minimal interruptions tend to perform better academically. Ensuring fair access to digital resources and dependable internet is essential to support inclusive education. Moreover, tailored training for learners and educators on how to navigate and use digital learning platforms is advised. In addition to direct learner engagement, support from parents or guardians, especially for younger students, plays an important role. Equipping families with strategies and materials to assist home-based learning may positively impact academic achievement. These combined measures can help transform virtual learning into a more inclusive, interactive, and effective educational experience.

CONCLUSION

The research findings reveal that students' encounters with online learning environments are heavily influenced by the presence or absence of critical infrastructural resources. Foremost among the challenges were the high costs and limited availability of mobile data, unstable and inconsistent internet connections, persistent electricity disruptions, and the strain of balancing academic schedules with demanding clinical placements. These impediments did not only disrupt learning continuity but also contributed to diminished enthusiasm and reduced levels of active participation in academic activities. These challenges resonate with broader patterns observed in contemporary studies, which highlight the vulnerability of students in under-resourced contexts during the transition to remote learning modalities.

Despite these adversities, a significant proportion of students maintained a sense of hope, anticipating improvements in learning conditions that would eventually facilitate a return to in-person learning formats. Their optimism underscores the resilience and adaptability of learners navigating unpredictable educational landscapes. Scholarly literature continues to underscore the formidable obstacles that both students and educators encountered during the sudden shift to online mathematics instruction amid the COVID-19 pandemic. Overcoming these multifaceted barriers necessitates comprehensive and targeted interventions. These should include sustained investment in digital

infrastructure, strategic professional development programmes for lecturers to effectively deliver mathematics content online, and the incorporation of learner-centred approaches that actively promote interactivity, problem-solving, and conceptual understanding. Enhancing the quality and inclusiveness of remote mathematics instruction, especially in times of systemic disruption, calls for deliberate planning, cross-sector collaboration, and pedagogical innovation tailored to local realities.

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