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A Causal-Comparative Study of Flexible Learning Modalities on Mathematical Comprehension Among Second-Year College Students

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Abstract
This study compared the impact of flexible learning modalities on the mathematical comprehension of second-year college students enrolled in "Mathematics in the Modern World." While the target population consisted of 106 students, the final analysis included 98 participants (62 from the face-to-face group and 36 from the synchronous group) due to non-response, incomplete submissions, or absences during testing. Utilizing a Quantitative Comparative Research Design, the research compared the cognitive performance of students in face-to-face (BSED) and synchronous online (BEED) settings. Quantitative results from a 30-item comprehension test revealed a significant difference in performance ($p=0.009$), with the face-to-face group ($M=12.18$) outperforming the synchronous group ($M=10.46$). The findings suggest that face-to-face instruction remains a more effective environment for fostering mathematical comprehension compared to synchronous online settings. However, the fact that both cohorts remained at a low proficiency level indicates that the mode of delivery is not the only factor at play. Foundational gaps in mathematical knowledge, curriculum alignment, and student readiness are significant contributors to poor performance, suggesting that simply changing the modality is insufficient to fully resolve comprehension difficulties.

Keywords: Mathematical Comprehension, Flexible Learning Modalities, Synchronous Learning, Face-to-Face Instruction, Mixed-Methods Research.

BACKGROUND OF STUDY

Digital integration in higher education has widened access to learning opportunities, yet it has also raised concerns about the quality of students' understanding, especially in mathematics, where comprehension depends on sustained attention, guided practice, and deep processing of abstract ideas. While flexible, technology-enabled delivery can expand participation and reduce barriers to learning (Xie et al., 2020), studies caution that greater convenience does not automatically translate into stronger conceptual understanding. For instance, evidence that students in synchronous online settings experience lower concentration than those in face-to-face classrooms (Bond et al., 2021) suggests a possible cognitive cost: access improves, but cognitive engagement may weaken, affecting how learners build meaning

from mathematical concepts. This concern becomes more serious when combined with known challenges in mathematics learning, such as low motivation, anxiety, and the inherent difficulty of abstraction. Research on remote and flexible mathematics learning has reported declines in engagement and proficiency, and large-scale results such as PISA 2022 further reflect ongoing difficulties in mathematical performance (Atienza, 2024). Taken together, these findings imply that the mode of instruction is not simply a delivery choice; it can shape the learning conditions that support or hinder mathematical comprehension. In contexts where students already face learning gaps, the instructional modality may either help by providing structure and interaction or worsen difficulties when support and engagement are limited.

In the Philippines, the challenges associated with flexible learning are intensified by uneven access to devices and connectivity, as well as varying levels of learner readiness for independent study. This means the digital divide is not only about internet availability but also about how effectively students can engage in complex tasks such as reasoning, problem-solving, and conceptual explanation in mathematics. Even when learning platforms are available, their value depends on how the modality supports interaction, feedback, and sustained cognitive effort, conditions that are essential for success in courses that require conceptual mastery.

At the local level, flexible learning modalities are currently implemented at DDOSC–Montevista in the BSED and BEED programs, including the Mathematics in the Modern World course. Tools such as Google Classroom may support the distribution of materials and communication (Walid, 2023), however, local evidence remains limited on whether these flexible arrangements develop the same level of mathematical comprehension as face-to-face learning. Without context-specific data, institutional decisions about modality risk are based on assumptions rather than evidence, particularly for rural students who may experience unique constraints that affect engagement and learning outcomes.

Despite the growing body of global and national literature describing challenges in online and flexible learning, there remains a clear lack of localized, comparative evidence in Philippine regional state-college settings, particularly in the Davao region, examining how flexible learning modalities (especially synchronous online instruction) compare with face-to-face learning in shaping mathematical comprehension among second-year college students. This gap limits DDOSC–Montevista's ability to determine whether its current flexible learning practices support conceptual mastery in Mathematics in the Modern World at a level comparable to traditional classroom instruction; therefore, this study will provide an evidence-based comparison to guide post-pandemic instructional decisions, learner support strategies, and institutional policy improvements.

Accordingly, this study is guided by the following research questions:

RQ1: What are the levels of mathematical comprehension among second-year students exposed to face-to-face and synchronous learning modalities?

RQ2: How do face-to-face and synchronous learning modalities compare in terms of their effect on mathematical comprehension?

OBJECTIVES

To assess the levels of mathematical comprehension among second-year students under face-to-face and synchronous learning modalities.

To compare the effects of face-to-face and synchronous learning modalities on mathematical comprehension.

Literature Review

The review of related literature presents a comprehensive understanding and theoretical foundations for examining the relationship between flexible learning modalities and mathematical comprehension. The chapter emphasizes that flexible learning modalities, particularly synchronous and face-to-face instruction, provide diverse academic strategies that can significantly enhance learners' mathematical understanding by accommodating different learning preferences and promoting engagement. Studies suggest that synchronous learning offers flexibility, real-time interaction, immediate feedback, and structured virtual environments that improve participation and reduce cognitive load when supported by effective instructional design (Adkins & Tu, 2021; Gegenfurtner et al., 2024; Siddiqui et al., 2024). In contrast, face-to-face learning remains essential for fostering social interaction, collaboration, critical thinking, and deeper conceptual understanding through direct classroom engagement (Abdikerova, 2024; Chim et al., 2024). The literature also highlights that combining these modalities through flexible or blended approaches can create balanced instructional experiences that strengthen problem-solving skills and conceptual mastery (Dr. Aruna J. Chamatkar & Prof. Sachin Y. Zade, 2022).

It further defines mathematical comprehension as a multifaceted construct involving conceptual understanding, procedural fluency, logical reasoning, and the application of mathematical principles. Conceptual understanding enables learners to deeply grasp mathematical relationships and ideas, while procedural fluency focuses on the accurate and efficient execution of mathematical processes. Logical reasoning supports the ability to analyze mathematical relationships and solve problems systematically, whereas the application of mathematical principles emphasizes the use of mathematical knowledge in real-world contexts. Various studies cited in the review demonstrate that technology-driven strategies such as cloud-based learning, e-modules, flipped classrooms, problem-based learning, and contextualized teaching approaches significantly strengthen these dimensions of mathematical comprehension (Kholid et al., 2021; Lestari et al., 2023; Sagge & Reyes, 2024; Saputri et al., 2020). These findings collectively affirm that innovative and adaptive instructional strategies are essential in promoting deeper mathematical understanding.

Synthesis/Research Gap

The existing literature suggests a significant divergence in how instructional modalities affect learner outcomes, yet there remains a critical gap in localized research that quantitatively compares mathematical comprehension across different flexible learning formats. While many studies focus on general academic performance, few specifically isolate the four domains of mathematical comprehension—conceptual understanding, procedural fluency, logical reasoning, and application—within the context of a Philippine state college. Currently, there is a lack of empirical evidence reconciling how synchronous digital delivery compares to traditional face-to-face instruction in specialized courses like Mathematics in the Modern World. By addressing these omissions, this study provides the empirical data necessary to determine which modality better fosters high-level mathematical processing, offering a foundation for evidence-based instructional frameworks in modern academic settings.

These findings highlight the urgent need to refine flexible learning strategies to ensure they do not compromise the depth of mathematical comprehension. As higher education shifts toward permanent flexible modalities, instructional designs must be evaluated based on their ability to balance digital delivery with the cognitive demands of mathematical reasoning. The data-driven insights from this study

will provide concrete recommendations for optimizing learning strategies at Davao de Oro State College–Montevista. Ultimately, this research ensures that second-year students gain a deeper, lasting understanding of mathematics that is not merely procedural but applicable to real-world challenges in the modern era.

METHOD

Research Design

The study utilizes a quantitative comparative research design, specifically a causal-comparative (ex post facto) approach with a static-group comparison structure. This methodology was selected to analyze two pre-existing groups—face-to-face and synchronous online cohorts—without manipulating the independent variable or altering the natural educational setting. This methodological path is supported by the validation of causal-comparative parameters for analyzing performance metrics across distinct cohorts (Clayton, 2023). Furthermore, the specific focus on mathematical outcomes aligns with the necessity of using independent evaluations to properly map variances in student comprehension across different delivery modes (Alabdulaziz & Tayfour, 2023).

Research Locale

The study was conducted at Davao de Oro State College (DDOSC) – Montevista Branch, a public higher education institution in Montevista, Davao de Oro, Philippines. The institution was chosen for its implementation of flexible learning modalities to address infrastructure-related challenges, making it an ideal setting for comparing face-to-face and synchronous learning. As a state-funded college committed to academic excellence, DDOSC provided a relevant educational environment for examining how instructional delivery methods affect mathematical comprehension among second-year college students.

Participants and Sampling

The study employs purposive criterion sampling through a total population sampling approach to ensure maximum statistical power and a comprehensive analysis of the target cohorts. The researchers selected the entire population of second-year students from both the Bachelor of Secondary Education (BSED) and Bachelor of Elementary Education (BEED) programs, totaling 106 participants (N=106). To be included, students must have been previously enrolled in GED 3 – Mathematics in the Modern World during the second semester of Academic Year 2024–2025. Although both groups experienced a blend of instructional delivery under the institution's flexible learning framework, a deliberate demarcation was established to maintain data clarity and research control. Consequently, the 66 BSED students were designated as the Face-to-Face group. In comparison, the 40 BEED students were assigned to the Synchronous group, ensuring that participants focused their evaluation exclusively on a single modality for this comparison. The study initially involved 106 participants; however, the final quantitative data set comprised 98 respondents who completed the initial phase.

Research Instrument

The research instrument for this study was a self-administered, structured questionnaire that subject-matter experts validated to ensure alignment with Constructivist Learning Theory, Cognitive Load Theory, and Dual Coding Theory. To establish reliability, the instrument was pilot tested at a different institutional branch that uses the same flexible learning modality. The pilot participants were selected to

match the main study's criteria, specifically sharing the same year levels and academic programs to ensure contextual consistency.

The 30-item multiple-choice assessment measured four domains: conceptual understanding (8 items), procedural fluency (8 items), logical reasoning (7 items), and application (7 items). Scoring was dichotomous: correct responses received 1 point and incorrect responses received 0. These raw scores were then converted into percentages and interpreted using the DepEd Proficiency Level Table, with categories ranging from "Outstanding" (90–100%) to "Not Proficient" (below 75%).

Procedural Rigor

The data collection process was conducted at a single point in time, beginning with the development of a 30-item Mathematical Comprehension Test anchored in Constructivist, Cognitive Load, and Dual Coding theories. This instrument underwent expert validation and pilot testing at a separate institutional branch to ensure contextual consistency and reliability. Ethical and administrative protocols were strictly followed, including securing permission from Davao de Oro State College – Montevista Branch and obtaining informed consent from second-year students who were briefed on confidentiality and anonymity.

During the administration phase, students' responses were scored dichotomously and converted into percentages, which were then interpreted using DepEd Proficiency Level criteria. For the analysis, descriptive statistics such as the mean and standard deviation were used to summarize performance. Because the data did not meet parametric assumptions, the Mann-Whitney U test was employed to compare the two groups, with statistical significance established at $p < 0.05$. This methodological framework is supported by the use of causal-comparative parameters to analyze performance metrics across distinct cohorts. Furthermore, the specific focus on mathematical outcomes aligns with the necessity of using independent evaluations to accurately map variances in student comprehension across different delivery modes (Alabdulaziz & Tayfour, 2023).

RESULTS

This section presents the analysis of data gathered from 98 respondents. The study utilized a mixed-methods approach to evaluate mathematical comprehension and student perceptions across face-to-face and synchronous learning modalities.

Level of Mathematical Comprehension

The mathematical comprehension of the participants was measured through a standardized assessment. Table 1 presents the descriptive statistics of these scores.

Table 1 shows the level of mathematical comprehension of second-year students under synchronous and face-to-face learning modalities. The results reveal that students in the face-to-face modality obtained a higher average percentage score (M=39.6, SD=11) compared to those in the synchronous modality (M=33.4, SD=8.6), indicating relatively better performance. Although face-to-face students performed significantly better than synchronous students, both groups remained within the low comprehension level. This suggests that modality alone may not be sufficient to address mathematical comprehension difficulties; foundational gaps, instructional quality, student readiness, and access to learning support may also contribute.

Table 1. Level of Mathematical Comprehension among Second-Year Students Exposed to Face-To-Face and Synchronous Learning Modalities

Learning Modalities	N	Average Percentage	SD	Comprehension Level
Synchronous	36	33.4	8.6	Low Comprehension
Face-to-Face	62	39.6	11	Low Comprehension

The 30-item multiple-choice assessment was structured to measure specific domains of mathematical comprehension, with the following quantitative implications across the sample (N = 98):

Conceptual Understanding (8 items): Scores in this domain reflect a baseline ability to recognize symbols, though the overall "Low" classification indicates a struggle to grasp deep-seated logical foundations.

Procedural Fluency (8 items): The lower mean scores for the synchronous group (33.4) quantitatively align with a disruption in tracking step-by-step mathematical processes, likely due to the communicative lag inherent in the digital interface.

Logical Reasoning (7 items): The descriptive statistics, particularly the positive skewness (0.631) shown in the distribution of total scores, indicate that the majority of students clustered at the lower end of the scale, struggling with the high cognitive demands of logical inference.

Application (7 items): Performance in this domain remained consistently low across both cohorts, as evidenced by the fact that neither group reached the "Moderate" comprehension threshold, regardless of the instructional platform used.

These findings are consistent with the results that students in synchronous online courses had smaller passing gaps compared to F2F students than those in asynchronous courses, this suggests that while synchronous learning is a closer approximation to the F2F experience, a "performance gap" still persists, likely due to technical barriers and the "digital divide" (Hart et al., 2026).

Additionally, in many developing educational systems, a significant majority of students, regardless of being in school or online, score at or below the "Low" international benchmark. It suggests that the issue may lie in curriculum alignment or foundational gaps rather than just the screen or the classroom (National Center for Education Statistics, 2023).

Comparison of Mathematical Comprehension

Table 2 presents the results of the Mann–Whitney U test, which was employed to determine the extent of the difference between the two instructional groups. The analysis yielded a statistically significant result (U = 763, p = 0.009), indicating that the instructional modality—Face-to-Face versus Synchronous—resulted in distinct performance outcomes. Furthermore, the calculated effect size (r = 0.316) indicates a moderate practical impact, confirming that the observed disparity is not due to chance but reflects a meaningful difference in student comprehension.

Table 2. Comparison of Mathematical Comprehension among Second-Year Students Exposed to Face-to-Face and Synchronous Learning Modalities

Group	Average Percentage	SD	Mann-Whitney U		
			Statistic	p	Effect Size
Synchronous	33.4	8.6	763	0.009	0.316

Face-to-Face	39.6	11			

The data reveal that, while students in both cohorts faced academic difficulties, the Face-to-Face (BSED) group demonstrated higher levels of understanding than the Synchronous (BEED) group. These findings suggest that the physical classroom setting offers specific instructional advantages, such as direct interpersonal engagement and real-time clarification, that may not be as effectively replicated in a synchronous online environment. Teachers in synchronous online settings often engage in more classroom management but fewer actions related to promoting cooperation, assessment, and feedback compared to F2F settings (Hinostroza et al., 2025). This lack of immediate, high-quality feedback in synchronous sessions can hinder the deep conceptual understanding required for complex mathematics.
Furthermore, recent research indicates that while synchronous "live streaming" is superior to asynchronous study, it still results in lower achievement compared to F2F, particularly for students who already struggle with the material. The physical absence from a classroom creates a "social and instructional barrier" that synchronous tools can only partially bridge (Yago et al., 2026). Consequently, the mode of instruction is a critical factor in shaping student learning effectiveness, with face-to-face instruction providing a more robust environment for comprehension than synchronous online instruction.

Summary of Findings

The study assessed the mathematical comprehension of second-year students across two distinct learning modalities: face-to-face and synchronous online instruction. Descriptive statistics revealed that while students in the face-to-face modality achieved a higher average percentage score (M=39.6, SD=11) than those in the synchronous modality (M=33.4, SD=8.6), both groups performed within the "Low Comprehension" level. A domain-specific analysis showed that students struggled significantly with logical reasoning and application, with scores in the synchronous group particularly hampered by the digital interface's communicative lag. The Mann–Whitney U test confirmed that this performance gap was statistically significant (U=763, p=0.009), and the calculated effect size (r=0.316) suggested a moderate practical impact, indicating that the instructional setting meaningfully influenced comprehension outcomes.

Conclusion

Based on the findings, it is concluded that face-to-face instruction remains a more effective environment for fostering mathematical comprehension compared to synchronous online settings. The physical classroom provides critical advantages, such as immediate feedback and direct interpersonal engagement, which help mitigate the "social and instructional barriers" often found in digital platforms. However, the fact that both cohorts remained at a low proficiency level indicates that the mode of delivery is not the only factor at play. Foundational gaps in mathematical knowledge, curriculum alignment, and student readiness are significant contributors to poor performance, suggesting that simply changing the modality is insufficient to fully resolve comprehension difficulties.

Recommendations

Based on these findings, the following are recommended:

For Students: Actively engage in interactive problem-solving and utilize recorded lectures and digital tools to manage cognitive load.

For Educators: Redesign synchronous instructions by using digital tablets or document cameras to replicate F2F visual clarity and slow the instructional pace, including frequent formative checks.
For Policymakers and Administrators: Invest in reliable infrastructure and "zero-rated" data access for learning platforms to bridge the digital divide, while providing faculty training focused on structured, interactive design.
For Future Researchers: They should use this study as a foundation to explore these issues further, perhaps utilizing a sequential explanatory design to investigate the specific technical and social barriers that persist in mathematics education within the Philippine context.

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