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Development of Flipped Classroom Learning Materials for Mathematics in the Modern World

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Abstract. The flipped classroom model has emerged as an effective strategy for enhancing student engagement and conceptual understanding in mathematics education. This study developed and validated flipped classroom learning materials for Mathematics in the Modern World (MMW) to address students' difficulties with abstract and conceptual topics. Using the Successive Approximation Model (SAM), a diagnostic assessment was first conducted among 100 first-year college students to identify the least mastered lessons: Where is Mathematics, How Mathematics is Done, Characteristics of the Language of Mathematics, and Some Elementary Logic, with correct response rates ranging from 20% to 40%. Based on these findings, four instructional modules were designed and later evaluated by 80 purposefully selected students and seven mathematics experts. The evaluation focused on four criteria: content, design, features, presentation, organization, and assessment tools. Descriptive statistics revealed that students and experts rated the materials as "good" (overall mean = 3.44), citing clarity, engagement, and alignment with learning objectives. Thematic analysis of qualitative feedback highlighted strengths in structure and multimedia use while recommending enhancements such as authentic assessments, interactive tasks, and standardized rubrics. The study concludes that the developed instructional materials are pedagogically sound and suitable for flipped learning environments, with suggestions for further refinement and broader implementation.

Keywords: Flipped classroom; Higher education; Instructional materials; Mathematics in the Modern World.

1.0 Introduction

For decades, traditional classroom instruction has been the dominant mode of teaching, characterized by direct teacher-centered lectures, passive student learning, and limited interaction. This conventional approach, where teachers deliver content through lectures and students take notes, has long been criticized for its inability to fully engage learners, encourage deep learning, and foster the development of critical thinking and problem-solving skills (Bergmann & Sams, 2012; Dagdag & Cardona, 2018; Dagdag, 2019; Dagdag, 2020). In mathematics education, in particular, students often struggle with conceptual understanding due to the abstract nature of the subject and the passive nature of traditional lectures (Bradford, Muntean, & Pathak, 2015). The challenges of engaging students in mathematics have led educators to explore innovative teaching methods that promote active learning and student-centered instruction (Dagdag, 2020).

The flipped classroom model is one such approach that has gained prominence in the 21st-century educational landscape. This pedagogical strategy reverses the traditional learning structure by requiring students to engage

with instructional materials, such as video lectures, readings, and interactive content, before attending in-person classes. The classroom then serves as a space for collaborative learning, problem-solving, and discussions facilitated by the instructor (Wang & Wang, 2020; Akçayır & Akçayır, 2018; Sergis, Sampson, & Pelliccione, 2018). The flipped classroom is grounded in active learning and constructivism, emphasizing that students learn best when they take an active role in their education rather than passively receiving information (Charles et al., 2024; Darling-Hammond et al., 2019; Yin, 2020).

In mathematics education, the flipped classroom model has effectively addressed students' difficulties with abstract concepts. Studies have shown that this approach enhances academic performance and improves engagement, motivation, and self-directed learning skills (Olasunkanmi & Oyarinde, 2023). However, the effectiveness of the flipped classroom heavily depends on the quality and structure of instructional materials. The need for well-designed learning materials that align with course objectives, support independent learning, and facilitate critical thinking is evident (Ahmed, Baloch, & Karim, 2024).

Mathematics in the Modern World (MMW) is a general education course introduced by the Commission on Higher Education (CHED) in the Philippines through CMO No. 20, s. 2013. It aims to provide students with an understanding of the role of mathematics in society, emphasizing its applications in real-world contexts. Unlike traditional mathematics courses that focus on computations and formulas, MMW highlights mathematics's conceptual, historical, and philosophical aspects, helping students develop a deeper appreciation for the subject. Despite its relevance, students often struggle with the course content, particularly in abstract topics such as mathematical language and logic (Torres-Peña et al., 2025).

While some instructional resources exist for MMW, they are primarily designed for conventional teaching methods and do not adequately support the flipped classroom model. The lack of interactive and technology-enhanced learning materials challenges educators seeking to implement this approach effectively. Given the increasing emphasis on technology integration in education and the demands of 21st-century learning, there is a critical need to develop instructional materials that facilitate self-paced learning and active engagement.

The transition to flexible learning models, accelerated by the COVID-19 pandemic, has highlighted the importance of innovative teaching strategies that leverage digital resources. The sudden shift to remote and hybrid learning environments exposed gaps in traditional instructional methods, reinforcing the necessity of adaptable, technology-supported educational approaches (Campillo-Ferrer & Miralles-Martínez, 2021). In this context, the flipped classroom has emerged as an effective alternative, allowing students to engage with course materials at their own pace before applying their knowledge in interactive classroom activities.

However, for the flipped classroom to be successful, educators must have access to high-quality, structured learning materials that align with learning objectives and support student engagement (Blau & Shamir-Inbal, 2017). Given the identified challenges in MMW, particularly in mathematical language and logic topics, there is a pressing need to develop instructional materials that address these difficulties while promoting a deeper understanding of mathematical concepts.

This study aimed to bridge the gap in instructional materials for Mathematics in the Modern World (MMW) by developing and validating a learning resource designed explicitly for the flipped classroom model. It sought to identify the least learned lessons among first-year college students and create instructional materials that effectively address these challenges while ensuring engagement, comprehensiveness, and suitability for a flipped learning environment. Furthermore, the study evaluated the acceptability of the developed materials based on student and expert assessments, considering aspects such as content, design, features and presentation, organization, and assessment tools. Lastly, feedback and suggestions from students and experts were gathered to refine and enhance the instructional materials for improved effectiveness.

2.0 Methodology

2.1 Research Design

This study employed a design-based research (DBR) approach to develop and validate a learning material for a flipped classroom setup in Mathematics in the Modern World (MMW). Design-based research is a systematic and

iterative methodology that focuses on creating, testing, and refining educational interventions to improve learning outcomes (Hoadley & Campos, 2022). Unlike traditional experimental research, DBR allows continuous refinement of instructional materials based on real-world classroom applications and expert feedback. Since this study aimed to develop a resource that could effectively support the flipped classroom model, DBR provided the flexibility needed to make iterative improvements while ensuring alignment with instructional goals.

To structure the development process, this study adopted the Successive Approximation Model (SAM), an iterative instructional design framework that facilitates ongoing evaluation and enhancement of educational materials. The SAM model consists of three key phases: (1) the preparation phase, which involves identifying learning gaps and analyzing student needs; (2) the iterative design phase, where instructional materials are developed and refined through expert input; and (3) the implementation and evaluation phase, which includes conducting trials, gathering feedback, and revising the materials accordingly. This structured yet flexible approach ensured that the instructional material was both pedagogically sound and user-friendly, making it well-suited for flipped classroom instruction.

This research design aligns well with constructivist learning theory, emphasizing student engagement, interactive learning, and iterative improvements (Wetzel & Farrow, 2021). The flipped classroom model, which requires students to engage with instructional content before in-class activities, depends on the availability of structured, engaging, and accessible learning materials. By integrating the SAM model within a constructivist framework, this study sought to ensure that the instructional material conveyed essential mathematical concepts and promoted active learning, self-directed study, and critical thinking.

2.2 Research Participants

The study was conducted at Isabela State University - Angadanan Campus during the first semester of the academic year 2024–2025. The university was chosen as the research setting due to its active engagement in improving mathematics education and its openness to adopting innovative teaching strategies such as the flipped classroom model. This institution provides a relevant context for investigating the effectiveness of technology-supported and student-centered learning materials, particularly in general education courses like MMW.

The research participants were carefully selected to represent a range of stakeholders involved in the learning process. The study involved 100 first-year students from the Bachelor of Science in Industrial Technology (BSIT) program for the initial diagnostic assessment. These students, who were enrolled in MMW as part of their general education curriculum, provided data on the least learned lessons in the course. After identifying these topics, another 80 first-year students from the Bachelor of Secondary Education (BSEd) program participated in the trial phase, during which they used the newly developed instructional materials and provided feedback on their effectiveness in a flipped classroom setting. Their evaluation focused on four key areas: (1) content, (2) design, features, and presentation, (3) organization, and (4) assessment tools. In addition to the student participants, seven external expert evaluators—mathematics professors from other campuses of Isabela State University—also reviewed and assessed the materials based on the same criteria.

A purposive sampling technique was employed to select participants. This approach ensured that students from different sections were included, making the sample more diverse and representative of the general student population. Additionally, expert evaluators were chosen based on their experience teaching MMW and participation in relevant training or seminars and including students and faculty members allowed for a comprehensive evaluation of the instructional materials from multiple perspectives.

2.3 Research Instrument

Three primary instruments were used in this study: a researcher-made test, a flipped classroom learning material, and a learning material evaluation instrument. The researcher-made test consisted of 50 multiple-choice questions covering fundamental concepts in MMW. The test aimed to determine the topics students found most challenging and was administered to the 100 BSIT students in the diagnostic assessment phase. Mathematics instructors reviewed the test to ensure its validity and alignment with CHED-prescribed competencies.

Based on the diagnostic test results, four instructional modules were developed: Where is Mathematics, How Mathematics is Done, Characteristics of the Language of Mathematics, and Some Elementary Logic. Each module followed a structured format with an introduction, clearly defined learning outcomes, well-explained content, interactive activities, and assessment tasks. The modules were designed by best practices in instructional material development, incorporating multimedia elements, guided exercises, and real-world applications of mathematical concepts. The flipped classroom approach necessitated learning materials that were not only informative but also engaging and self-explanatory, as students would interact with the content before attending in-person classes.

The learning material evaluation instrument was adapted from Isabela State University's Evaluation of Learning Materials framework. This four-point Likert scale questionnaire assessed the instructional material regarding content, design and features, organization, and assessment tools. Students who participated in the trial implementation and expert evaluators used this instrument to provide quantitative ratings and qualitative feedback. The Likert scale ranged from 1 (strongly disagree) to 4 (strongly agree), ensuring that responses were systematically categorized for analysis.

2.4 Data Gathering Procedure

The data collection procedure followed the three phases of the SAM model. In the preparation phase, the diagnostic assessment was administered to 100 BSIT students to identify the least learned topics in MMW. The iterative design phase involved the development of instructional materials based on the diagnostic test results. The modules were reviewed and refined through expert feedback, ensuring they aligned with the flipped classroom pedagogy and were suitable for self-paced learning. The instructional materials were piloted with 80 BSEd students in a flipped classroom setup during the implementation and evaluation phase. Students engaged with the modules before attending class, where they participated in guided discussions, problem-solving activities, and group work. After completing the learning activities, students and expert evaluators filled out the evaluation questionnaire, providing ratings and feedback on the materials.

2.5 Data Analysis

The quantitative data collected through the evaluation questionnaire were analyzed using descriptive statistics, particularly mean and standard deviation computations. The mean scores calculated from the four-point Likert scales were described as follows: needs improvement if within 1.00 to 1.74, fair if within 1.75 to 2.49, satisfactory if within 2.50 to 3.24, and good if 3.25 to 4.00. These measures helped determine the overall acceptability of the learning materials, highlighting strengths and areas for improvement. Qualitative data from student and expert feedback were analyzed using thematic analysis to complement the numerical findings.

2.6 Ethical Considerations

This study adhered to ethical research principles to ensure the rights and well-being of participants. Before the data collection process, informed consent was obtained from all students and expert evaluators. They were fully informed about the study's objectives, procedures, and potential benefits. Participation was voluntary, and individuals could withdraw at any time without consequences. The confidentiality of participant responses was strictly maintained, and data were used solely for research purposes. Additionally, the instructional materials developed in this study were designed to be inclusive and accessible, considering students' diverse learning needs and backgrounds.

3.0 Results and Discussion

3.1 Diagnostic Assessment

The study began with a diagnostic assessment administered to 100 first-year BSIT students to identify the topics in MMW that students found most difficult. The results (Table 1) revealed four key topics with the lowest correct response rates: *Where is Mathematics?* (20%), *How Mathematics is Done?* (39%), *Characteristics of the Language of Mathematics* (30%) and *Some Elementary Logic* (40%). The students struggled with conceptual aspects of mathematics, particularly those related to its nature, reasoning processes, and communication.

Table 1. *Least learned lessons in the Mathematics in the Modern World course*

Topics	Score	No. of Items	% Score	Rank
Mathematics in Our World				
1. What is mathematics?	183	300	61%	6th
2. Where is Mathematics?	60	300	20%	1st
3. What is Mathematics for?	166	300	55%	4th
4. What is Mathematics about?	268	600	45%	3rd
5. How is Mathematics done?	117	300	39%	2nd
6. Who uses Mathematics?	174	300	58%	5th
Mathematics Language and Symbols				
1. Characteristics of the Language of Mathematics	60	200	30%	1st
2. The English Language and The Mathematical Language	128	300	43%	4.5th
3. Conventions in the Mathematical Language	186	300	62%	8th
4. Grammar in the Mathematical Language	179	300	60%	7th
5. Four Basic Concepts	127	300	42%	3rd
6. Translating Expressions and sentences	296	500	59%	6th
7. Some Elementary Logic	280	700	40%	2nd
8. Quantifiers	129	300	43%	4.5th

3.2 Development of the Instructional Material

Based on the diagnostic assessment results, the study developed a flipped classroom learning material consisting of four instructional modules corresponding to the least learned topics (see Figure 1). Each module was designed to support self-directed learning and active engagement, aligning with best practices in constructivist learning theory. The modules included a structured format comprising an introduction, learning outcomes, learning content, teaching and learning activities, assessment tasks, and references. The instructional materials incorporated multimedia components, such as videos and interactive exercises, to enhance student engagement. The emphasis on self-paced learning aimed to accommodate diverse learning styles, allowing students to revisit challenging topics at their convenience. Additionally, the modules included real-world applications of mathematical concepts, addressing the need to make mathematics more relevant and meaningful for students. The development of these materials followed the Successive Approximation Model (SAM), an iterative instructional design framework that allows for continuous refinement based on expert and student feedback.

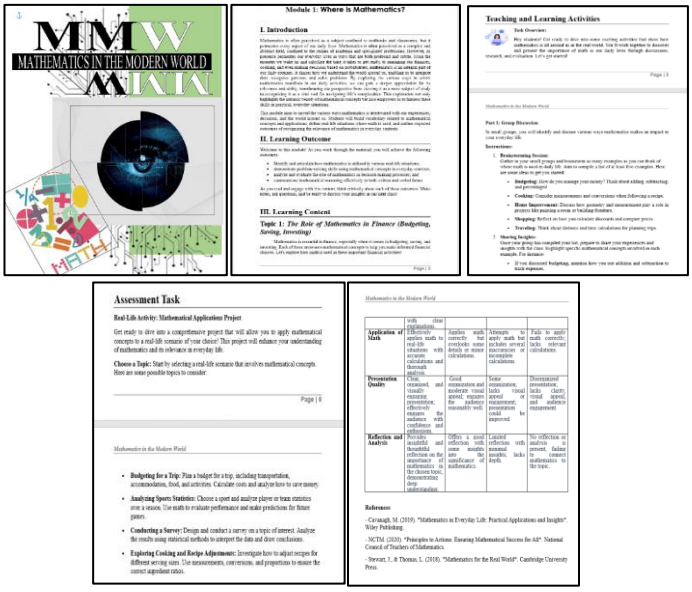

Figure 1. *Sample part of the developed learning material*

3.3 Evaluation of the Learning Material's Acceptability

To determine the effectiveness of the developed instructional material, 80 first-year BSEd students who used the material in a flipped classroom setting and seven mathematics instructors who served as expert evaluators participated in an evaluation process. The assessment covered four key areas: content, design and features, organization, and assessment tools (see Table 2).

Table 2. *Quality of the Developed Learning Material ffor the Subject Mathematics in the Modern World*

Criteria	Students		Experts		All		Description
	M	SD	M	SD	M	SD	
Content	3.37	0.70	3.60	0.40	3.39	0.68	Good
Design, Features, and Presentation	3.45	0.61	3.61	0.36	3.46	0.59	Good
Organization	3.48	0.63	3.29	0.85	3.47	0.65	Good
Assessment Tools	3.43	0.61	3.54	0.49	3.44	0.60	Good
Overall Rating	3.43	0.64	3.51	0.53	3.44	0.63	Good

As shown in Table 2, the developed flipped classroom learning material for *Mathematics in the Modern World* received favorable evaluations from student users and expert raters. The overall mean rating across all criteria was 3.44 (SD = 0.63), interpreted as Good on the four-point Likert scale. Among the specific domains assessed, organization (M = 3.47, SD = 0.65) and design, features, and presentation (M = 3.46, SD = 0.59) obtained the highest ratings, indicating that the material was well-structured and visually engaging. These findings suggest that students found the modules easy to navigate and visually supportive of their learning process—qualities essential in a flipped classroom where learners must engage with content independently before class sessions.

The content component of the material was rated with a mean of 3.39 (SD = 0.68), also falling within the "Good" range, reflecting students' overall satisfaction with the clarity and relevance of the lessons. Meanwhile, the assessment tools garnered a mean rating of 3.44 (SD = 0.60), indicating that students perceived the embedded exercises and evaluations as appropriate for reinforcing understanding. While slight variations in standard deviations suggest differing individual experiences, the consistently high mean scores across all categories support the conclusion that the instructional material was compelling and well-received. These results affirm the material's suitability for flipped classroom implementation in general education mathematics courses at the tertiary level.

3.4 Student and Expert Feedback for Improvement

Qualitative feedback from students and expert evaluators was analyzed using thematic analysis to complement the quantitative evaluation results. The open-ended responses were coded into four recurring themes: content clarity, instructional design, student engagement, and assessment methods. Based on the participants' firsthand experiences, each theme reflects key areas of the instructional material's strengths and areas for improvement.

Content Clarity

Feedback from students and experts emphasized the clarity of explanations, appropriateness of language, and relevance of the examples provided in the modules.

Student 06: *"The explanations were clear and easy to understand. I liked how the lessons used real-life situations instead of just formulas and definitions."*

Expert 03: *"The content was well-organized and accurate. However, some terms may still be too technical for non-math majors. Simplifying those could improve accessibility."*

The recurring feedback suggests that the content was generally accessible and aligned with learners' needs. However, experts noted that further scaffolding—such as inserting definitions for unfamiliar terms or examples with increasing complexity—may benefit students with limited mathematical background.

Instructional Design

Participants consistently highlighted each module's structured format and logical flow, which aligned with best practices in instructional material design.

Student 11: *"Each module starts with clear objectives and ends with assessments. That helps me focus on what to expect and what to learn."*

Expert 06: *"The instructional design aligns well with the flipped classroom framework. It promotes independent learning and reduces reliance on teachers."*

These responses reflect the effectiveness of using the Successive Approximation Model (SAM) to structure content. The consistent sequence—introduction, learning outcomes, main content, activities, and assessments—helped establish cognitive routines among learners. Experts appreciated the logical layout, but a few recommended incorporating differentiated materials to cater to students with varying levels of prior knowledge.

Student Engagement

Students reported that multimedia elements such as embedded videos, visual diagrams, and reflective tasks enhanced their learning experience. However, experts suggested additional interactive components to sustain engagement.

Student 28: *"The videos made it easier to understand the topic. I can pause and replay them until I get it."*

Expert 05: *"Some modules could benefit from embedded gamified elements or branching activities to maintain interest throughout."*

The feedback affirms that multimedia integration promoted engagement. Students appreciated being able to study at their own pace. Experts proposed further integrating technology-enhanced strategies such as simulations, branching scenarios, and formative quizzes to elevate engagement to a higher level.

Assessment Methods

Participants recognized the value of having in-module assessments to track learning progress, but both students and experts recommended improvements in assessment variety, alignment with learning outcomes, and feedback mechanisms.

Student 09: *"The assessments helped me know if I understood the lesson. I hope there were more types of questions, like true or false or fill-in-the-blank."*

Expert 02: *"The inclusion of formative assessment is good, but the materials need more authentic assessments aligned with higher-order thinking skills."*

Experts emphasized the importance of varied, performance-based assessment types to promote critical thinking. To encourage real-world application, the use of the GRASPS model (Goal, Role, Audience, Situation, Product, and Standards) was recommended. Additionally, standard rubrics were proposed to ensure consistency in evaluation and clarity in expectations.

3.5 Students' Learning Challenges in MMW

The diagnostic test results underscore the difficulties students face in recognizing mathematics beyond its conventional academic boundaries. The lowest-scoring topic, Where is Mathematics, suggests that many students fail to connect mathematics with real-world applications, reflecting a common misconception that mathematics is an isolated discipline rather than an integral part of daily life (Nedaei et al., 2021; Schoenfeld, 2016). Similar challenges were noted in How Mathematics is Done, which requires students to grasp abstract reasoning and mathematical proofs, areas where prior studies indicate students often experience cognitive overload due to unfamiliarity with deductive thinking (Ovadiya, 2021).

Moreover, difficulties in Characteristics of the Language of Mathematics and Some Elementary Logic indicate that students struggle with mathematical communication and reasoning. Unlike natural language, mathematical language has a precise and symbolic structure that students must interpret correctly to engage in problem-solving

and logical deduction (Morgan, 2020; Tall, 2013). This finding aligns with research suggesting that students' difficulties in logic-based reasoning stem from weak foundational skills in mathematical symbols and structures (Bronkhorst et al., 2022).

These results validate the need for instructional approaches that move beyond rote memorization and procedural learning and foster conceptual understanding and real-world connections. The flipped classroom model, emphasizing self-paced, interactive, and applied learning, presents a promising alternative to traditional lecture-based instruction.

3.6 Effectiveness of the Flipped Classroom Learning Materials

The instructional material development followed an iterative process based on the Successive Approximation Model (SAM), ensuring that the modules were continuously refined to meet student needs. The evaluation results indicated that students and expert evaluators rated the learning materials as Good across all assessment criteria, particularly in design and features, organization, and assessment tools. These findings align with existing research on instructional design, which emphasizes the role of well-structured and visually appealing materials in improving student engagement and comprehension (Vattøy & Gamlem, 2024; Belisle et al., 2019).

One of the key strengths of the flipped classroom materials was their integration of multimedia elements, such as instructional videos and interactive exercises, which have been shown to enhance student motivation and retention of complex mathematical concepts (Alias & Razak, 2024). Cognitive Load Theory (Sweller, 2011) suggests that when instructional materials are designed to reduce extraneous cognitive load—such as through clear visuals and structured content—students are more likely to focus on meaningful learning. This was reflected in students' positive feedback, highlighting how the flipped classroom approach allowed them to revisit content at their own pace and engage more actively in classroom discussions.

Despite the high acceptability ratings, expert evaluators noted that while the content was accurate and comprehensive, additional scaffolding could further support students struggling with abstract mathematical ideas. This is consistent with Vygotsky's (1978) Zone of Proximal Development (ZPD) theory, which emphasizes that students learn best when instructional materials provide appropriate guidance levels before transitioning to independent learning.

3.7 Areas for Improvement and Future Enhancements

While the instructional materials received positive evaluations, expert and student feedback revealed areas for further enhancement. One recommendation was the integration of authentic assessment techniques, particularly the GRASPS model (Goal, Role, Audience, Situation, Product, Standards), which promotes real-world problem-solving and application-based learning (Wiggins & McTighe, 2005). Studies have shown that authentic assessment strategies, particularly those involving applied tasks and project-based evaluations, improve students' ability to transfer mathematical knowledge to real-life scenarios (Boaler, 2016).

Experts recommended incorporating higher-order thinking activities, such as open-ended mathematical investigations and problem-based learning tasks. Research indicates that higher-order cognitive tasks requiring analysis, evaluation, and synthesis lead to deeper understanding and improved long-term retention of mathematical concepts (Saparbayeva et al., 2025). By incorporating these elements, future iterations of the instructional material could further enhance students' critical thinking and problem-solving skills.

A final area for improvement was the need for standardized rubrics to ensure consistency in assessing student performance. Clear assessment criteria help students understand expectations and provide grading transparency, fostering a more supportive learning environment (Lim, 2024; Streifer & Palmer, 2021). Aligning assessment tools with well-defined rubrics would enhance the reliability and fairness of evaluations in a flipped classroom setting.

4.0 Conclusion

This study confirms the effectiveness of a structured, interactive, and student-centered approach in improving students' understanding of Mathematics in the Modern World. The diagnostic assessment identified key learning

gaps in conceptual and abstract topics, underscoring the need for innovative instructional strategies. The development and evaluation of the flipped classroom materials addressed these challenges, with positive feedback from both students and experts. Integrating multimedia, real-world applications, and iterative improvements enhanced engagement and comprehension. However, further refinements should incorporate authentic assessments, problem-based tasks, and standardized grading rubrics to optimize learning outcomes.

To maximize the benefits of flipped learning, the instructional materials should be integrated into the MMW curriculum alongside faculty training for effective implementation. Authentic assessments, such as the GRASPS model, should be incorporated to foster real-world problem-solving. Interactive exercises, including digital simulations and applied tasks, should reinforce conceptual mastery. Standardized rubrics must ensure objective grading and self-assessment. A continuous evaluation process, supported by pre- and post-tests and feedback mechanisms, will guide necessary revisions. Expanding flipped learning materials to other mathematics courses and securing institutional support for faculty training will enhance instructional quality. Future research should explore its broader impact on mathematical literacy across diverse educational settings.

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All authors contributed equally to this study.

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7.0 Conflict of Interests

The author declares that there is no conflict of interest.

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