# From Tools to Thinking: Using Accessible Digital Platforms and RME Tasks to Deepen Mathematical Understanding in Architecture Students

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**Abstract:** *This study explores how accessible digital tools such as Rayon Design, Procreate, and Autodesk Sketchbook enhance students' mathematical understanding and engagement among architecture students through tasks informed by Realistic Mathematics Education (RME). Implemented in the context of the* Mathematics in the Modern World *general education course, the tasks centered on core mathematical concepts such as the Fibonacci sequence, the Golden Ratio, and related patterns. These were designed to integrate mathematical thinking with real-world contexts, particularly, the Sustainable Development Goals (SDGs). Implemented with second-year architecture students in a university of the Philippines in the academic year 2024-2025, results show that such tools promote conceptual learning, spatial reasoning, and interdisciplinary connections. The study highlights the potential of familiar, accessible technologies to support meaningful, context-rich mathematical learning in design-oriented disciplines.*

## 1. Introduction

Real-world design is essential in visual disciplines such as architecture, where accuracy and realism play a crucial role. This highlights how mathematics serves as a fundamental framework for interpreting and constructing reality [1]. The emergence of accessible digital tools has further strengthened the relationship between mathematical principles and architectural design, making the design process faster, more accurate, and capable of producing visually compelling results [2, 3].

Various accessible software tools were used by architecture students to enhance the visualization of their creative ideas, while still adhering to mathematical concepts and design constraints. In this context, the use of Realistic Mathematics Education (RME) is emphasized, as the tasks are made more meaningful and connected to real-life situations. RME views mathematics as a "human activity" [4] allowing students to engage with problems in ways that reflect their own experiences. As a domain-specific educational theory, RME promotes student agency by fostering ownership over learning and a sense of pride in the integration of mathematics into their design work [5].

Contemporary challenges such as climate change, poverty, and resource depletion demand a reimagining of educational goals. In response, the United Nations' Sustainable Development Goals (SDGs) have been adopted by many institutions as a framework for preparing students to contribute to a sustainable future [6]. Embedding sustainability within mathematics education requires instructional strategies and task designs that integrate SDG-related themes [7]. For example, students may be tasked with designing a sustainable classroom that aligns with specific SDGs, such as Sustainable Cities and Communities, Affordable Housing, and Climate-Resilient Infrastructure. These tasks aim to develop in students with the knowledge and skills needed to become more resilient and proactive in shaping a sustainable future.

For architecture students, the ability to experiment with visual and conceptual tools during early design stages is crucial [8]. While they may not rely on advanced design software at this phase, accessible tools that support ideation and communication are invaluable [9]. Students are often deliberate in selecting platforms that best match their design intentions, leading to more flexible, expansive, and responsive creative processes. This study, therefore, explores how RME-informed instructional design, combined with accessible digital technologies, can deepen students' mathematical understanding and engagement within a design-oriented learning context [10].

## 2. Realistic Mathematics Education in Higher Education

In the Philippines, mathematics instruction remains largely traditional, often emphasizing rote procedures and abstract content with limited connection to students' lived experiences) [11]. Realistic Mathematics Education (RME), a domain-specific instructional theory developed in the Netherlands, offers an alternative pedagogical approach by framing mathematics learning as a "human activity" [12]. The theory emphasizes leveraging learners' real-world experiences as a foundation for developing formal mathematical understanding. At the tertiary level, RME often involves more complex representations and interdisciplinary integration to reflect authentic contexts [13].

RME is anchored in several key concepts: mathematization**,** didactical phenomenology**,** use of models**,** and guided reinvention [14]. These principles provide a framework for designing learning environments where students actively engage with problems, discover patterns, and build mathematical meaning from contextual situations.

The application of RME in higher education is particularly relevant, as it helps bridge the often-significant gap between secondary and tertiary mathematics by embedding real-life scenarios into the learning process [15]. This approach discourages an overreliance on procedural thinking and instead promotes conceptual understanding and critical reasoning. The emphasis on modeling is essential for contextualized, student-centered problem solving, making RME especially valuable in fields such as architecture, engineering, economics, and data science, where real-world applications of mathematics are fundamental [16]. Moreover, the integration of technology: such as simulations, dynamic modeling tools, and data analysis software, further enhances the implementation of realistic contexts in mathematical tasks [17].

Designing tasks within the RME framework represents a shift from traditional lecture-based instruction to a more exploratory and participatory mode of learning, where students take ownership of the process and express their creativity. However, this approach requires intensive and sustained professional development for instructors, as student outcomes can vary significantly when working with open-ended and context-rich problems [18]. Teachers must be equipped to facilitate learning environments that accommodate diverse interpretations and solution strategies.

In order to effectively implement these pedagogical principles, it is necessary to make use of tools that align with the creative processes of students. Accessible digital platforms, in this context, function as conduits between mathematical reasoning and architectural design expression.

## 3. Accessible Digital Tools in Architecture Education

Architectural education as a visual discipline demands tools that demonstrate both creativity and precision [19]. With the advancement of technology, digital tools are now readily available and accessible. The shift from traditional hand-drawing to hybrid workflows has significantly enhanced the speed and accuracy of visual outputs [20]. As a result, accessibility and affordability have become key considerations for students, particularly those new to the field.

For beginners, there are several digital tools to choose from, especially in the areas of sketching and space planning. In terms of sketching tools, students commonly use Procreate and Autodesk SketchBook. Procreate, available on iPad/iOS, is favored for its intuitive interface, pressure sensitivity, and portability. Key features include layers, a wide variety of brushes, and perspective guides. Autodesk SketchBook, compatible with Windows, Mac, iOS, and Android, offers predictive stroke technology, rulers, and symmetry tools, ideal for early-stage conceptualization [21].

For layout and space planning, students often choose Rayon Design, a web-based application tailored for architectural and interior layout design. Its key functionalities include drag-and-drop components, dimensioning, and a scalable grid system. It also supports collaboration through its export options for design documentation.

The rise of these accessible digital tools in design disciplines opens opportunities for integrating mathematics education into creative design tasks. These tools support blended learning environments, where time efficiency is crucial for producing and revising outputs promptly [22]. Rapid feedback and iterative design are more feasible, and the lower barrier to entry reduces dependence on high-end software, particularly beneficial for general education courses and newcomers entering the discipline.

While understanding the technological landscape is crucial, an equally important aspect of this study is how these tools were implemented and evaluated within the context of an actual classroom. The following section discusses the methodology used to collect and analyze student outputs and reflections.

## 4. Methodology

This study used a qualitative case study approach to explore how RME-based mathematical tasks, supported by accessible digital tools, influenced students' conceptual understanding in a general education mathematics course. In this study, mathematical understanding within the context of Realistic Mathematics Education (RME) is defined as the ability to relate mathematical concepts to real-world contexts and apply these concepts in design. This includes using them to make decisions in their designs and articulating their design in their creativity. Student engagement on the other hand may be behavioral (use of digital tools), cognitive (creative exploration of mathematical ideas) and emotional (interest in designing).

### 4.1 Participants and Context

The participants of the study were second-year architecture students enrolled in *Mathematics in the Modern World* at the university where architecture is a quota course during the second semester of Academic Year 2024–2025. This course, part of the mandated General Education curriculum in Philippine higher education, provides an opportunity to contextualize mathematics in real-world settings. The activity involved two classes of approximately 40 second-year architecture students from a university in the Philippines during the 2024–2025 school year. However, only 19 students agreed to let their work be analyzed for this study. Even with this small group, the results offer meaningful insights into how digital tool can support interdisciplinary education in design oriented disciplines. Ethical guidelines were observed: participation was voluntary, informed consent was obtained, and anonymity was ensured in reporting.

### 4.2 Instructional Design

The instructional activity was anchored on RME principles and aligned with selected United Nations Sustainable Development Goals (SDGs). Students were first introduced to mathematical concepts such as the Fibonacci sequence, the Golden Ratio, and mathematical patterns found in nature. They were then tasked with producing a sustainable classroom design. The design task was intended to function as both a learning activity and an embedded assessment, requiring students to integrate mathematical reasoning with creative design decisions and sustainability considerations. Alongside the design, students submitted written reflections.

### 4.3 Instruments

In this study, no traditional pen-and-paper assessments (e.g., quizzes or pre/post-tests) were administered. Instead, two instruments were employed in the study:

(1) Performance Task (Design Output): The design task served as the primary means of assessing students' ability to apply mathematical concepts in an authentic, design-oriented context.

(2) Reflection Prompts: Written reflections functioned as a complementary instrument, capturing students' insights into their learning processes, tool use, and the integration of mathematics and sustainability in their work. The students were guided by prompts that asked them to:
   - Explain how mathematical concepts informed their design,
   - Describe how their design addressed sustainability themes related to the SDGs, and
   - Reflect on their choice and experience with the digital tools used.

The written reflections offered deeper insights into students' thought processes, experiences, and conceptual understanding. They served as a valuable qualitative lens for examining how learners engaged with mathematical concepts—particularly the Fibonacci sequence and the Golden Ratio—within design tasks. These reflections further highlighted how students translated abstract mathematical ideas into tangible design solutions and how they began to perceive mathematics as an integral part of both the natural and built environment.

Together, the design outputs and reflective journals were analyzed for indicators of mathematical understanding, such as proportional accuracy, pattern recognition, and the ability to explain math-driven design decisions. This performance-based, authentic approach allowed the study to track student progress and validate the learning outcomes through the quality and depth of student work.

### 4.4 Data Collection

Students were first introduced to core mathematical concepts such as the Fibonacci sequence, the Golden Ratio**,** and related mathematical patterns. After which the lectures on these topics, they were given the performance task designed in accordance with the principles of Realistic Mathematics Education (RME) and aligned with selected United Nations Sustainable Development Goals (SDGs)**,** ensuring that the mathematical learning experience was both contextualized and socially relevant.

Data were drawn from two primary sources:

(1) **Digital Design Outputs** – Project files created with digital tools, which provided direct evidence of mathematical application in authentic, design-oriented contexts.

(2) **Written Reflections** – Guided journals in which students explained how mathematical concepts influenced their designs, how sustainability was incorporated, and how their choice of digital tools supported their process.

### 4.5 Data Analysis

This study was limited to a single instructional unit within the *Mathematics in the Modern World* course and therefore did not track student outcomes across an extended period. Within this unit, student understanding and engagement were assessed through performance-based design tasks and reflective activities that captured immediate learning outcomes. While this approach provided valuable insights into students' engagement and conceptual development during the intervention, the findings represent a snapshot rather than a longitudinal account of learning trajectories. Nonetheless, the detailed analysis of student design outputs and reflections yielded rich evidence of meaningful engagement and conceptual growth, suggesting the potential of accessible digital tools to support mathematical learning in design-oriented contexts.

In the framework of Realistic Mathematics Education (RME), mathematical understanding in this course was conceptualized as the ability to recognize, apply, and integrate mathematical ideas into real-world designs, thereby fostering appreciation of the role of mathematics in the creative process of architecture. Specifically, five indicators were used to assess student learning:

(1) Recognition of Mathematical Ideas
(2) Application of Mathematical Concepts in Design
(3) Connection to Real-World Contexts (in relation to the SDGs)
(4) Creative Integration of Mathematics
(5) Reflection and Articulation of Appreciation

Moreover, tool engagement was analyzed by exploring students' rationale for selecting specific digital platforms and their reflections on how these tools supported their design processes and mathematical thinking.

The next section presents a selection of student work and reflections, illustrating how accessible digital tools and RME-informed tasks translated into meaningful learning outcomes.

## 5. Sample Students' Outputs and Reflection

This section presents three sample student outputs using three different accessible tools used by students.

### *5.1.1 On Rayon Design*

Figure 4.1 shows a screenshot of the student who used Rayon Design as his tool to design the task. It features the Fibonacci Sequence and the Golden Ratio in the design of the classroom. Metaphorically, he used droplets to show concentric circles and to show further the natural radial symmetry the recursive and expanding nature of the sequence.

The student's output reflects a deepened understanding of the elements of design found in Fibonacci Sequence and Golden Ratio by transforming abstract mathematical concepts into real-world design elements. It emphasizes further the proportional thinking and spatial logic of the student, bringing the dimension's functionality by incorporating sustainability and understanding the symbolic nature and sensory to the design. Student's reflection shows the interdisciplinary application of mathematical knowledge with emotional and practical design thinking.

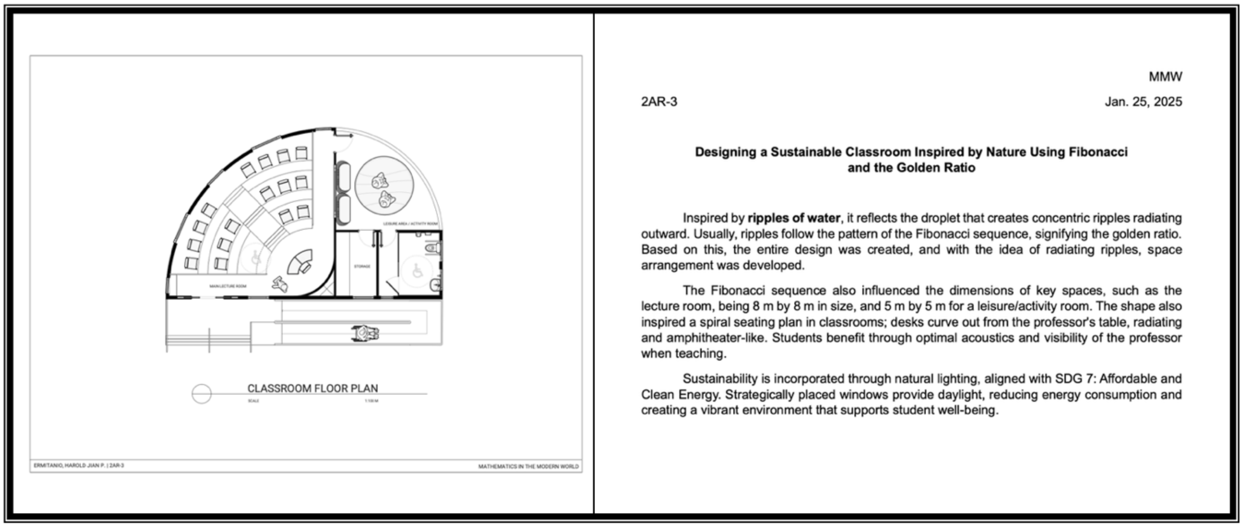


**Figure 5.1** Screenshot of the student work using Rayon Design

### *5.1.2 Procreate*

Figure 4.2 shows the student's output using Procreate guided by Fibonacci Sequence and Golden Spiral as mathematical concepts in the creation of a college lecture room. The layout demonstrated spatial hierarchy to show proportionality according to function making sure of the aesthetic and functionality present. The student's reflection highlighted that mathematics is not an isolated field but one that can be integrated with architecture, design, sustainability, and symbolic meaning. Furthermore, the student noted how patterns can create efficient, harmonious, and meaningful spatial arrangements.

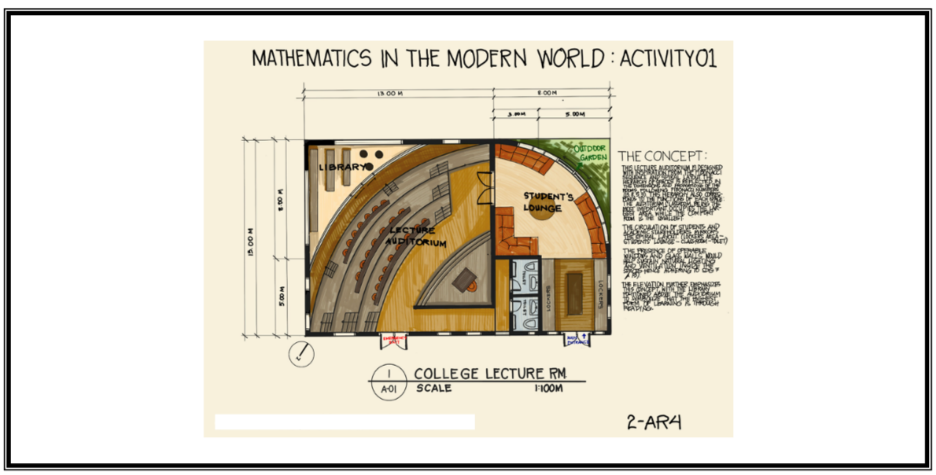


**Figure 5.2** Screenshot of the student work using Procreate.

### *5.1.3 AutoDesk Sketchbook*

A student using Autodesk SketchBook incorporated the Fibonacci sequence and Golden Spiral into the floor plan and window shape (See Figure 4.3) The student reflected on how mimicking branching patterns of the tree show the influence of geometric forms on spatial flow, perception, and emotional response. Additionally, the design was linked to developmental psychology to show mathematical patterns can support cognitive and emotional development.

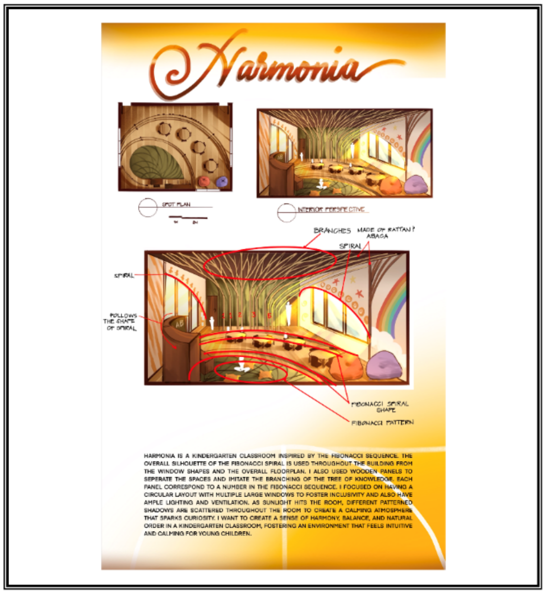


**Figure 5.3** Screenshot of the student work using AutoDesk Design

## 6. Results and Discussion

This section presents the findings of the study, highlighting how students engaged with mathematical concepts through their design outputs and reflective writings. The results are organized around five indicators of mathematical understanding—recognition, application, connection to real-world contexts, creative integration, and reflection/appreciation. Each indicator is discussed with supporting evidence from student outputs and reflections, followed by interpretations that link the results to the principles of Realistic Mathematics Education (RME) and the interdisciplinary goals of design-oriented learning.

### 6.1. Recognition of Mathematical Ideas

Student outputs revealed a consistent ability to identify and reference core mathematical principles**,** particularly the Fibonacci sequence and the Golden Ratio. Many designs incorporated spirals, proportional divisions, or ratios as the foundation of their classroom layouts. For instance, one student explicitly described:

*"The overall silhouette of the Fibonacci spiral is used throughout the building—from the floor plan to the window shapes."*

This recognition demonstrates that students were not only able to recall these concepts but also to visualize them in design contexts. In line with RME, this shows the early stage of mathematization—where abstract mathematical ideas are recognized within meaningful situations.

## 6.2. Application of Mathematical Concepts in Design

Beyond recognition, students demonstrated the ability to apply mathematical concepts to guide proportions and spatial arrangements**.** The Golden Ratio was often used to balance functional and aesthetic aspects of classroom spaces, while the Fibonacci sequence informed seating layouts and circulation patterns. One design output illustrated proportional desk arrangements based on Fibonacci numbers, which the student explained as an attempt to harmonize utility and flow.

This finding suggests that students were not treating mathematics as a decorative add-on but as a structuring principle in architectural design**.** Such application reflects deeper conceptual understanding, moving from recognition to practice.

## 6.3 Connection to Real-World Contexts

Reflections and outputs showed that students made strong connections between mathematics and authentic, real-world contexts**,** particularly sustainability and natural inspiration. Several designs drew from natural patterns such as tree branching, shells, or plant growth. One student explained:

*"Each wooden panel in my classroom corresponds to a number in the Fibonacci sequence. This imitates the branching of the tree of knowledge, while also ensuring inclusivity through natural light and ventilation."*

These reflections highlight the students' awareness of the interdisciplinary relevance of mathematics**,** aligning with SDGs such as sustainable cities, affordable energy, and climate action. This indicator underscores how contextualized mathematical tasks promote not just cognitive understanding but also socio-environmental awareness.

## 6.4. Creative Integration of Mathematics

Students went beyond direct application to creatively integrate mathematical concepts into innovative design solutions. For example, one student used droplets arranged in concentric Fibonacci patterns to symbolize growth and harmony in the classroom. Another incorporated branching spirals into the floor plan to guide spatial flow and emotional response.

Such outputs illustrate how mathematics can serve as both a functional and symbolic design element**,** blending aesthetics with practicality. This creative integration aligns with RME's principle of guided reinvention, where learners build ownership of mathematics by embedding it into personal and meaningful creations.

## 6.5 Reflection and Articulation of Appreciation

Finally, students' written reflections revealed a growing appreciation for the role of mathematics in the creative process**.** Several students explicitly noted that mathematics is not an isolated discipline but one that interacts with architecture, sustainability, and human experience. As one student reflected:

*"Mathematics is not an isolated field but one that can be integrated with architecture, design, sustainability, and symbolic meaning."*

Such statements indicate a shift in perception—from viewing mathematics as abstract and procedural to recognizing its cultural and interdisciplinary significance**.** This attitudinal dimension is particularly valuable, as it suggests that performance-based, design-oriented tasks can foster positive dispositions toward mathematics.

## 6.6 Engagement with Digital Tools

Observations and student reflections indicated high levels of engagement with the digital tools used in the study. Students reported that applications such as Procreate, Rayon, and SketchBook enhanced their ability to visualize and refine mathematical ideas in their designs. Procreate was particularly valued for its intuitive interface and flexibility in sketching, while Rayon allowed students to experiment with layouts and proportional adjustments quickly. SketchBook was praised for its symmetry and predictive stroke features, which supported precision in incorporating spirals and ratios into design elements.

The choice of tools was often framed by accessibility, prior familiarity, and the specific design intention of each student. Importantly, students emphasized that these tools lowered the barriers to translating mathematical patterns into aesthetic and functional design outputs**,** thus supporting their learning and creativity. These findings suggest that the integration of accessible digital technologies provides both motivational and cognitive support**,** as students felt empowered to explore mathematical ideas through platforms aligned with their design practices.

## 7. Summary and Implications

Overall, the results highlight that when mathematics is embedded in meaningful, design-oriented tasks, students demonstrate both conceptual understanding and positive engagement. The performance-based nature of the task enabled students to demonstrate mastery not through rote memorization or symbolic manipulation but through creative, context-driven application. This resonates with prior studies on RME, which emphasize real-world tasks as powerful vehicles for deepening mathematical understanding.

The findings also underscore the importance of interdisciplinary learning. By situating mathematics within architecture and sustainability, students began to see mathematics not as an isolated discipline but as a tool for shaping functional, socially responsive, and aesthetically meaningful designs. The integration of SDG-related themes reinforced the broader relevance of mathematics in addressing authentic global challenges.

At the same time, the enthusiastic adoption of digital tools demonstrates that technology functions as more than just a medium—it serves as a catalyst for bridging abstract mathematics with tangible design. This aligns with the literature on educational technology, which points to the role of digital platforms in fostering experimentation, iteration, and visualization.

**8. Conclusion**

This study illustrates how accessible digital tools with RME-based task design can enhance mathematical understanding among architecture students. By allowing students to connect abstract mathematical concepts with tangible, real-world applications, the tasks fostered creativity, spatial reasoning, and interdisciplinary thinking. The results highlight how tools such as Rayon Design, Procreate, and Autodesk SketchBook can serve not only as design aids but also as platforms for engaging with mathematical ideas in meaningful ways. Findings support the integration of RME in higher education in the Philippines and provide a compelling case for its broader application in design-related disciplines. Future research could extend this work by tracking student progress across multiple units and semesters, employing more rigorous assessment tools, and exploring the integration of additional digital technologies. Investigating other disciplines could further validate the interdisciplinary potential of this approach. Future studies also may build on these findings by implementing longitudinal designs to monitor the persistence and evolution of mathematical understanding and engagement across multiple course units or academic terms.

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