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Research article

Implementation of a modular learning approach in mathematics: An examination of students' performance, perceptions, and experiences

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Abstract: The COVID-19 pandemic transformed educational delivery in the Philippines, leading to the widespread use of modular learning, particularly in contexts with limited access to digital instruction. Although adopted as an emergency modality, modular learning has potential as a flexible learning approach for mathematics, though few researchers have investigated its effectiveness and student experiences in a post-pandemic setting. In this study, I examined modular learning in mathematics by analyzing the cognitive demands embedded in the modules, describing students' conceptual performance after implementation, and exploring students' perceptions and learning experiences, including differences between high- and low-performing learners. I employed a descriptive mixed-methods design using a one-group posttest-only approach with qualitative support. Participants were 123 Grade 10 students from a laboratory high school in Northern Mindanao, Philippines, during the second quarter of academic year 2024–2025. Quantitative data were collected through a 45-item posttest and a perception questionnaire and analyzed using descriptive statistics, while qualitative data from semi-structured open-ended questions administered to purposively select high- and low-performing students were analyzed thematically. Posttest results yielded a mean score of 27.66 out of 45 (61.5%) with a standard deviation of 6.72, indicating moderate variation in student performance. Students also reported favorable perceptions of the modular approach (M = 4.06). Thematic analysis generated seven themes: collaborative learning, use of resources, problem-solving strategies, benefits of the modality, aspects to retain or improve, challenges encountered, and support mechanisms. My findings suggest that modular learning provides opportunities for engagement, self-directed learning, and collaboration in mathematics while emphasizing the need for enhanced scaffolding and contextualized tasks to strengthen conceptual understanding and application. The study contributes to the growing literature on post-pandemic modular learning by providing evidence of students' performance, perceptions, and experiences with modular mathematics learning.

Keywords: self-directed learning, modular learning approach, conceptual performance, perceptions and experiences, high- and low-performing students

1. Introduction

The COVID-19 pandemic significantly transformed the delivery of education in the Philippines, particularly in public schools where limited internet connectivity necessitated the rapid adoption of modular distance learning. Printed self-learning modules became the primary learning medium [1], especially in subjects such as mathematics, which is often perceived as challenging due to its abstract and sequential nature. Although initially implemented as an emergency response, modular learning has demonstrated potential as a flexible learning approach that promotes learner independence. Well-designed modules have structured content, clear learning goals, and guided activities that enable students to learn at their pace, promoting autonomy, persistence, and self-regulation in learning [2,3].

Post-pandemic studies on modular distance learning (MDL) indicate that its effectiveness varies depending on implementation conditions such as teacher preparedness, instructional design, and contextual constraints. Fernandez et al. [4] emphasized that MDL outcomes are highly dependent on implementation quality and recommend structured developmental improvements to enhance instructional delivery. Similarly, researchers [5] have largely focused on learner outcomes and implementation challenges, with limited comparative analysis of learning models within printed modular contexts. In mathematics education, student performance is influenced by learning preferences and engagement strategies, with visual and kinesthetic modalities often associated with improved achievement in self-directed environments [6]. However, qualitative studies also show that learners face challenges in comprehension, motivation, and engagement, even as they develop self-regulated learning strategies and resilience [7].

STEM education debates center on how education design can balance structured scaffolding with learner autonomy, particularly in contexts where modular learning is used as an alternative to technology-enhanced approaches. Inquiry-based learning, gamification, and TPACK-informed design have been shown to improve conceptual understanding and collaboration [8], while modular and technology-enhanced assessment systems improve formative feedback when teacher facilitation is provided [9]. As a result, modular learning has gained popularity as a more accessible and adaptable teaching method. However, questions remain about its effectiveness in promoting deep conceptual understanding, maintaining student motivation, and supporting self-regulated learning. Despite these advances, persistent challenges remain, including limited teacher interaction, self-regulation difficulties, and contextual barriers such as connectivity issues and household responsibilities [10]. This study fits into these debates by exploring how modular learning can be designed and implemented to promote student engagement, autonomy, and conceptual understanding.

From a theoretical perspective, modular learning aligns closely with self-directed learning (SDL), as it requires students to plan, monitor, and evaluate their learning processes. Such autonomy supports the gradual development of problem-solving and self-monitoring skills, which are essential in mathematics education. SDL further emphasizes flexibility in learning pace, enabling high-performing students and those requiring additional support to progress according to their needs. The modality particularly is suitable for mathematics, where conceptual gaps often hinder progression. Studies have shown that SDL is associated with improved attitudes toward mathematics, enhanced metacognitive skills and higher academic achievement [11,12]. However, effective independent learning also requires instructional scaffolding, as highlighted by Meniano and Tan [13], who identified challenges in printed modules such as complex content, language barriers, lack of guidance, and inconsistent quality. These findings suggest that autonomy alone is insufficient; structured support is necessary to facilitate comprehension and metacognitive engagement.

Despite the growing body of research, the literature on modular learning in mathematics remains limited in several key areas. Most researchers focus on implementation issues, learner challenges, or general perceptions, with insufficient attention given to how modular learning supports students' conceptual understanding of mathematics. Additionally, there is limited exploration of how learners experience and interpret mathematics learning through modules, particularly in post-pandemic classroom contexts. Furthermore, researchers rarely differentiate learner groups, despite the likelihood that high-performing students (HPSs) and low-performing students (LPSs) engage with modular materials differently in terms of strategies, independence, and collaboration. The identified gaps call for a more nuanced investigation into cognitive outcomes and learner experiences in modular mathematics education.

In response to these gaps, I aim to examine modular learning in mathematics by focusing on three key areas: (1) The extent to which modular learning supports students' conceptual understanding of mathematics; (2) how students perceive and experience learning mathematics through modular approaches; and (3) how and why HPSs and LPSs differ as they engage with modular learning independently and collaboratively. By addressing these objectives, I seek to contribute to a better understanding of how modular learning influences not only student outcomes but also the cognitive and experiential processes involved in learning mathematics.

2. Theoretical lens supporting modular learning in mathematics

I use complementary theoretical frameworks to explain how modular learning improves conceptual understanding, learner autonomy, and other skills such as higher-order thinking in mathematics.

In this study, modular learning refers to an instructional approach in which learning is organized into modules that structure content, activities, and assessments to enable relatively independent study. This research is grounded in complementary theoretical frameworks that, taken as a whole, provide a conceptual basis for the use of modular learning in mathematics, especially when it comes to developing students' conceptual knowledge, independence, and higher-order thinking abilities. It is primarily based on constructivism, which holds that students actively create knowledge through engagement, investigation, and reflection. Instead of being passive recipients, students in modular learning engage in tasks and problems that call for independent meaning-making at their pace. Precellas and Napil [14] found that constructivist learning environments are associated with student engagement, critical thinking, motivation, and SDL readiness. Thus, meaningful learning experiences and autonomy may support participation and the application of knowledge in real-world situations. Complementing the learning process is SDL, which emphasizes learners' responsibility for regulating their learning. Modular learning aligns with the SDL theory as it requires students to manage pacing, monitor progress, and take responsibility for outcomes. According to Kharroubi [15], SDL promotes learner autonomy by enabling individuals to control their educational experiences, making it an essential component of modular learning design.

The study is also supported by the Zone of Proximal Development (ZPD) and Cognitive Load Theory (CLT). ZPD emphasizes scaffolding to connect what learners can do alone with what they can achieve with guidance. Thus, modular learning incorporates structured progression through sequenced activities ranging from basic to complex, aided by scaffolds such as guided examples and step-by-step instructions. ZPD-based instruction entails systematically bridging learners' current and potential levels of development using adaptive support [16]. Moreover, CLT explains that learning is optimized when instructional design takes into account the limitations of working memory. To reduce cognitive overload, modular learning breaks down content into manageable segments and incorporates worked-out examples. Sozio et al. [17] confirmed that worked examples are associated with improved learning outcomes when compared to unguided problem-solving.

Together, these frameworks explain how modular learning promotes mathematical understanding through a network of interconnected mechanisms. First, structured modular design reduces cognitive overload by breaking down content into manageable chunks, enabling students to focus on key concepts. Second, scaffolded activities and guided examples help learners progress from basic understanding to more complex problem-solving by providing temporary, gradually decreasing support. Third, SDL processes enable students to control their pace, monitor their comprehension, and adjust their strategies, all of which are essential in independent learning contexts. Finally, constructivist task engagement encourages students to make active meaning by connecting new knowledge to prior understanding.

Through these mechanisms, modular learning is expected to improve not only students' conceptual understanding of mathematics but also their autonomy and ability to engage in higher-order reasoning.

3. Methods

In this section, I outline how the study was conducted, including the research design, participants, instruments, and procedures used to gather and analyze data. The approach was structured to provide a clear picture of how the modular learning approach was implemented and evaluated, ensuring transparency and coherence in the research process.

3.1. Research design

I employed a convergent mixed-methods design. Quantitative data were collected through a posttest and a Likert-scale questionnaire. Qualitative data were collected using semi-structured open-ended questions administered through Google Form to gain a better understanding of students' experiences and to explain the quantitative data. Moreover, a one-group posttest-only design was used as a type of quasi-experimental approach, which is often used when practical constraints limit the inclusion of a pretest or a comparison group [18]. In this design, a single group of participants was exposed to the intervention, and data were collected afterward through a posttest to evaluate the learning modality.

Because all Grade 10 sections received the same topics, pacing, and assessment timeline under a shared instructional plan, establishing a non-treatment comparison group was not feasible without disrupting regular instruction or withholding the intervention from some students. Moreover, I focused on completing and revising the module, and I was unable to develop a diagnostic test that covered all the topics in the module. The exploratory nature of the research, as well as the realities of classroom implementation, guided my methodological choices.

3.2. Research participants and setting

The study involved 128 Grade 10 students from a laboratory high school affiliated with a state university in Northern Mindanao, Philippines. These students were organized into four intact sections, which followed the same curriculum, learning competencies, and instructional schedule as prescribed by the school. The sections were administratively grouped rather than ability-tracked, and all were handled under a common instructional framework to ensure consistency in content delivery and learning expectations. The same teacher-developed modular materials were implemented across all sections during the second academic quarter.

A total of 123 students (96% response rate) completed the learning activities and data collection instruments. I aimed to include the entire Grade 10 cohort; thus, the primary inclusion criterion was formal enrollment in Grade 10 during the implementation period. No additional exclusion criteria were imposed to preserve the natural classroom setting and reflect authentic instructional conditions. Students who did not complete all required data (n = 5) were treated as non-respondents and were excluded from the final analysis.

To address the objective of comparing learning experiences across performance levels, posttest scores of the 123 participants were used to rank students. The top 10% were classified as HPS (n = 12), while the bottom 10% were identified as LPS (n = 12). These groups were purposively selected to represent contrasting achievement levels. Participants in each group were assigned codes (e.g., H1, H2 for HPS; L1, L2 for LPS) to ensure anonymity. The classification of students enabled a focused comparison of their learning experiences, strategies, and engagement with the modular approach following its implementation.

3.3. Instruments

Three research materials were utilized in this classroom-based action research: a teacher-made module, a 45-item multiple-choice test, and a ChatGPT-assisted Likert scale perception questionnaire.

3.3.1. Description of learning activities embedded in the modules

I was the researcher and the teacher and created the module to meet the unique learning needs of students and improve mathematics learning in the classroom. It was designed in alignment with the curriculum standards and included lesson objectives, conceptual discussions, worked examples, learning activities, and formative assessments. The module emphasized contextual application and classroom-based improvement, ensuring that its content, structure, and activities were clear, appropriate, and consistent with the prescribed learning competencies. The module covered various mathematical topics, including graphing, domain and range, solving equations, word problems, and concepts involving square root functions, absolute value functions, piecewise functions, composition, and inverse functions, which are part of the DepEd K–12 mathematics curriculum in the Philippines [18] and were implemented during the second quarter of the school year 2024 - 2025 for approximately five weeks.

The analysis of the modules revealed that the tasks were intentionally designed to address multiple levels of cognitive demand, from application to reasoning, and to incorporate diverse activity types, including concept exploration, guided examples, and formative assessments. While learners can exhibit emerging functional thinking, research on students' comprehension of functions consistently reveals that they frequently struggle with translating and coordinating multiple representations, especially graphical and algebraic forms, which limits their ability to fully grasp relationships between variables [19].

The teacher-made modules were guided by constructivist and learner-centered pedagogical principles, particularly SDL and elements of problem-based learning (PBL), which emphasize active knowledge construction, learner autonomy, and meaningful engagement with mathematical concepts [20,21]. The design of learning activities followed three key criteria: progression in cognitive demand (from procedural fluency to conceptual reasoning) [22], integration of multiple representations (symbolic, graphical, and numerical) [23], and contextual relevance through real-life applications [24]. Tasks were intentionally sequenced to scaffold understanding, beginning with guided examples and advancing toward open-ended, reasoning-based, and function-construction activities that required justification and reflection.

a. Square Root Function and Absolute Value Function Modules

At the application level, students worked on graphing and transformation tasks that required them to apply prior knowledge to new function types, such as identifying vertices, domains, and ranges and comparing square root and absolute value graphs under transformations. These guided examples aided conceptual exploration by connecting equation parameters to graphical changes.

Students analyzed how operations inside or outside radical and absolute value symbols affected orientation, position, and structure as part of reasoning tasks that emphasized conceptual and representational understanding. Rather than relying on procedural memory, these exercises required students to justify patterns and generalize transformation rules across function families.

The modules also included formative assessment tasks such as reflection, justification, and open-ended problem-solving activities in which students created functions that met specified conditions. These tasks facilitated creative reasoning and metacognitive engagement, which are associated with higher-order thinking.

These activities can be interpreted in light of research, indicating that students' difficulties with square roots are frequently context-dependent and best understood through routines and discourse patterns rather than isolated procedural errors [25]. Similarly, research on absolute value misconceptions indicates difficulties in interpreting piecewise behavior and switching between arithmetic and algebraic representations [26]. Together, these findings help to explain the importance of structured conceptual and representational support.

The activities are also consistent with Kop et al. [27], who linked symbol understanding to success in algebraic and graphing tasks. Hand-graphing and reasoning activities encourage integrated symbolic, graphical, and conceptual understanding. The analyzed materials collectively demonstrate a strong coherence between task design, learning outcomes, and cognitive demand, which supports self-directed and conceptually grounded mathematical learning.

b. Piecewise Function Module

At the application level, students worked on table representation and interpretation, graphing linear components across domains, and combining rules to form coherent piecewise graphs. These tasks encouraged the integration of numerical, algebraic, and graphical representations while developing an understanding of how function segments behave at interval boundaries.

Reasoning tasks involved analyzing graph features such as holes and discontinuities and explaining them using domain restrictions and function definitions. Such activities made students' reasoning explicit and were consistent with formative assessment practices. As Rittle-Johnson [28] observed, prompting students to explain reasoning promotes deeper conceptual understanding and transfer.

Students also created piecewise-defined functions across intervals using forms such as linear and quadratic expressions, which necessitated attention to domain constraints, continuity, and graph structure. These open-ended tasks encouraged metacognitive reflection and the integration of symbolic and graphical representations.

Contextualized modeling tasks placed pieces of functions in familiar Philippine settings, such as mobile load usage, tricycle fares, and electricity billing. These problem-solving tasks linked abstract concepts to real-world situations, thereby enhancing relevance and retention, consistent with existing findings [29–31]. Research also shows that students frequently rely on local visual graph features rather than global interpretations, which contributes to problems with domain and range in piecewise functions [32] and supports the module's emphasis on representational and reasoning-based tasks.

c. Operation, Composition, and Inverse Functions

At the recall and application levels, students worked through guided examples and skill-building exercises involving algebraic expressions. These tasks were of low-to-moderate demand and aimed to help students develop procedural fluency and confidence, which served as a foundation for more advanced reasoning. As Schifter and Russell [33] emphasized, learning that goes beyond correct answers supports reasoning about mathematical relationships.

The module introduced function operation and composition tasks such as domain evaluation, combination, and behavior analysis. Students used expressions such as (□+□)(□), (□ □ □)(□), and (□/□)(□) to reason function interactions rather than isolated manipulations.

Conceptual explanation and representation tasks, such as mapping diagrams for one-to-one relationships, were used to enhance conceptual understanding. Uscanga et al. [34] found that generating examples can deepen internalization of function concepts.

Students used higher-order reasoning skills to visually compare related functions to identify transformations, similarities, and inverse relationships. Reflective justification tasks then challenged them to explain why a function must be one-to-one to have an inverse, engaging them in mathematical argumentation.

Supporting this learning approach, studies on technology-enhanced learning suggest real-world modeling environments may strengthen conceptual understanding and motivation [35]. Likewise, research on inverse functions shows students often struggle with symbolic and graphical interpretations, supporting the value of structured and scaffolded tasks for meaningful understanding [36].

3.3.2. Multiple-choice test

The 45-item multiple-choice test served as the students' second-quarter examination and was constructed by me to measure their understanding of the concepts covered in the module. A Table of Specifications (TOS) was prepared to ensure balanced coverage of topics and cognitive levels (knowledge, comprehension, and application). The test underwent face validation by me to check item clarity, relevance, and alignment with the curriculum. Although the instrument was not pilot-tested or externally validated, it followed standard classroom assessment practices and was designed for completion within one hour.

3.3.3. ChatGPT-assisted Likert scale perception with a semi-structured open-ended reflection questionnaire

A ChatGPT-assisted Likert scale perception questionnaire was administered to gain insights into students' experiences with modular learning in mathematics. The instrument, which was also utilized by me in a parallel study [37], underwent face validation and was refined for contextual appropriateness. Internal consistency was evaluated during data collection, yielding a Cronbach's alpha of 0.9251, indicating excellent reliability. A series of semi-structured, open-ended reflection questions was used to supplement quantitative data to document students' experiences with the modular learning approach in mathematics. Students were asked to explain how they solve problems, describe what they do in class, and give examples of how the modality helped them learn. It also inquired about difficulties faced and the assistance required to overcome them. To gather more detailed reflections from HPSs and LPSs, it was disseminated through Google Forms, enabling the triangulation of quantitative and qualitative insights. The instruments utilized in the study were developed within the framework of action research, focusing on classroom-based improvement rather than large-scale generalization. Despite the absence of external validation and empirical reliability testing, the use of a TOS and adherence to curriculum standards strengthened the materials' content alignment and instructional relevance.

3.4. Data collection

The teacher-made mathematics modules were designed to promote engagement and SDL among Grade 10 students. Grounded in principles of contextualized and self-regulated learning, the modules included lesson objectives, conceptual discussions, guided examples, structured exercises, and formative assessments. ChatGPT was used only to generate initial drafts of contextualized examples and suggest revisions to the wording and sequencing of selected activities. The researcher reviewed, revised, and finalized all outputs to ensure curriculum alignment and appropriateness. Additionally, I made the final content decisions for the module. Each unit incorporated diverse tasks intended to stimulate interest and foster independent problem-solving, consistent with Pokhrel and Sharma's [11] view that varied instructional strategies support learner motivation and autonomy.

The modules were organized thematically to enable students to focus on one mathematical topic at a time, thereby reducing cognitive overload and promoting deeper conceptual understanding. The modular approach was implemented over one academic quarter with limited teacher facilitation to emphasize learner independence. Students completed tasks during class hours and at home, with teacher support deliberately limited to preserve the self-directed nature of the intervention. I provided only clarification of instructions, addressed procedural questions, and offered brief feedback only when students encountered persistent difficulty. Moreover, I did not deliver full-class lectures or step-by-step demonstrations of solutions; instead, assistance was given on a needs basis, typically through short verbal prompts or guiding questions. Feedback was provided informally during class interactions and focused on helping students reflect on their strategies rather than supplying direct answers to ensure that learners remained primarily responsible for engaging with and completing the modular tasks independently.

To address the research objectives, data were collected using three instruments: a 45-item multiple-choice posttest, a Likert-scale perception survey, and an open-ended reflection questionnaire. The posttest was used to assess students' conceptual performance following the implementation of the modular approach. The perception survey examined students' attitudes and experiences in learning mathematics through modules. The open-ended questionnaire gave qualitative insights into HPS and LPS learning processes, challenges, and strategies, thereby enriching the interpretation of quantitative findings.

To address the objective of comparing the experiences of HPS and LPS, participants were categorized based on their posttest results. A purposive selection of HPSs and LPSs (n = 12 per group) students was then identified for in-depth analysis. Their responses to the open-ended questions were analyzed thematically and compared to examine differences in engagement, collaboration, problem-solving approaches, and self-regulation when interacting with the modular activities, independently and collaboratively. This procedure ensured that I focused on identifying similarities and differences in learning experiences between performance groups.

Students were given one week to complete the online perception survey and semi-structured open-ended questionnaire. The perception survey was administered prior to the posttest to minimize response bias. The posttest was then conducted during the scheduled periodic examination under the supervision of the classroom adviser.

3.5. Data analysis

A combination of quantitative and qualitative analyses was employed to address the research objectives and ensure a comprehensive understanding of students' learning experiences. For the quantitative component, descriptive statistics were used to analyze data from the 45-item multiple-choice test and the perception survey. Histograms and boxplots were created to evaluate the distributions of key variables and identify possible outliers [38]. Means and standard deviations were computed to summarize students' posttest performance and perception scores. Although Likert-scale data are ordinal, they were treated as approximate interval measures [39], a widely accepted practice in educational research. Mean ranges and corresponding verbal interpretations are presented in Table 1. Inferential analysis was not pursued since the study was exploratory and classroom-based in nature.

Table 1. Likert scale interpretation.

Mean Range	Interpretation
4.21 - 5.00	Strongly Agree
3.41 - 4.20	Agree
2.61 - 3.40	Neutral
1.81 - 2.60	Disagree
1.00 - 1.80	Strongly Disagree

The qualitative component consisted of thematic analysis of students' semi-structured open-ended reflections. The process involved "familiarization with data, generating initial codes, searching for themes among codes, reviewing themes, defining and naming themes, and producing the final report" (Braun & Clarke, 2013, as cited in [40]). Themes were compared between high-performing and low-performing students to identify common and contrasting experiences. Findings from the thematic analysis were then triangulated with quantitative results to generate an integrated interpretation of students' understanding, perceptions, and experiences with the modular learning approach in mathematics.

4. Results

4.1. Students' conceptual performance

The analysis of the 123 responses using the 45-item multiple-choice questionnaire yielded the following key statistics: An average score of 27.66, or roughly 61.5% of the total possible score, indicating that most students were able to grasp more than half of the assessed content. The result reflects a moderate level of understanding of the topics delivered through the modular approach. The standard deviation of 6.72 highlights some variability, indicating that while most performed close to the average, several students scored significantly higher or lower.

The histogram in Figure 1 shows a clustering of most scores between 20 and 35, with a slight peak around the 28–33 range. The pattern aligns with the findings for the mean of 27.66, suggesting a fairly symmetrical distribution. The trend is further supported by the KDE curve, which is the smooth line superimposed on the histogram and shows a distribution that is similar to the normal curve. Kernel density estimation (KDE) supports the creation of visualizations such as violin plots, heatmaps, and contour plots by modeling a discrete sample of data as a continuous distribution [41].

Figure 1. Histogram of scores.

The boxplot in Figure 2 places the median at 28, with an interquartile range (IQR) spanning approximately from 23 to 33. A few outliers appear on the lower end, particularly around scores of 14–18, which may account for some of the observed spread. Overall, the data remain relatively concentrated in the middle, indicating consistent performance across the student group [42].

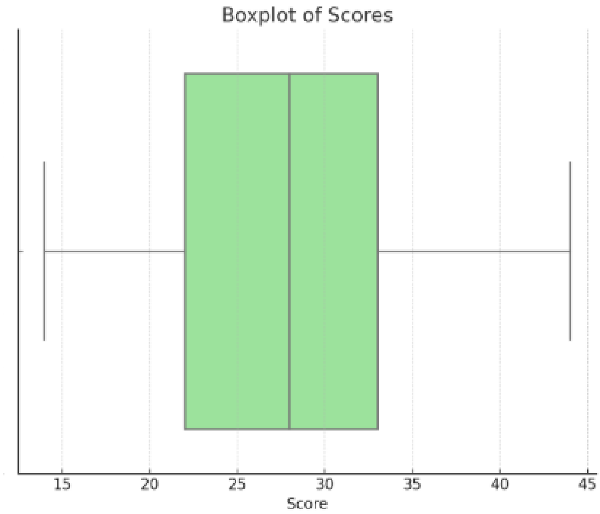

Figure 2. Boxplot of scores.

4.2. Students’ perception of modular learning

Modular learning, which uses self-learning modules to guide students through lessons and assessments, has reshaped the way learners engage with education. While it offers flexibility and continuity, especially during disruptions such as the COVID-19 pandemic, it also brings challenges in comprehension, motivation, and support. Exploring students’ perceptions, as shown in Table 2, is essential to understanding its effectiveness and areas for improvement.

Table 2. Students’ perception of modular learning.

Indicators	Mean	SD	Interpretation
Using the modular learning approach implemented in class is effective in enhancing my learning.	4.10	0.72	Agree
The modular learning approach is well-suited to the course content.	4.15	0.83	Agree
The activities in the modular learning approach are innovative and engaging.	4.20	0.79	Agree
I feel comfortable participating in class activities under the modular learning approach.	4.37	0.80	Strongly Agree
The modular learning approach aligns with my preferred learning style.	4.05	0.93	Agree
The modular learning approach helps me understand complex topics more effectively	3.76	0.94	Agree
I feel more motivated to complete assignments and tasks because of this modular learning approach.	3.98	0.93	Agree
The modular learning approach encourages me to think critically about the subject.	4.11	0.79	Agree
This modular learning approach has positively influenced my academic	4.07	0.85	Agree

performance.			
I feel more confident in applying what I have learned in real-world scenarios under the modular learning approach.	3.78	0.91	Agree
I am satisfied with the modular learning approach learning modality used in this class	4.25	0.85	Strongly Agree
This modular learning approach has enhanced my overall learning experience compared to other methods.	4.05	0.91	Agree
I would recommend this modular learning approach for other subjects.	3.95	1.01	Agree
Overall	4.06	0.866	Agree

The results of the perception survey reveal generally favorable evaluations of the implemented learning modality, suggesting positive student engagement and learning. Among the items assessed, the highest mean score was recorded for the statement, "I feel comfortable participating in class activities under the modular learning approach" (M = 4.37), indicating that the learning environment is perceived as supportive and inclusive. Additionally, the high level of overall satisfaction (M = 4.25) reinforces the students' positive reception of the modality.

Students also expressed agreement that the approach is suitable for the course content (M = 4.15) and aligned with their preferred learning styles (M = 4.05). The relatively strong rating for "The methods used are innovative and engaging" (M = 4.20) highlights the appeal of the learning strategies employed. Moreover, the students reported agreement that the modality motivates them to complete academic tasks (M = 3.98) and fosters critical thinking (M = 4.11), suggesting perceived engagement in cognitive processes. Furthermore, a strong correlation between motivation levels and mathematical achievement, as well as between the acceptability of self-learning modules and mathematical achievement, was found in the Gadingan [43] study. The results suggest that students' academic achievement in mathematics is associated with high levels of motivation and well-designed self-learning modules.

Students reported that the modality had a positive effect on their academic performance in terms of perceived learning outcomes (M = 4.07). However, slightly lower ratings were observed for statements concerning the understanding of complex topics (M = 3.76) and the application of learning to real-world contexts (M = 3.78). These results may indicate a need for further refinement to enhance depth of understanding and promote knowledge transfer beyond the classroom.

4.3. Experiences of high- and low-performing students in modular learning implementation

Given that the results indicated some variation, and while most students' performance was close to the average, with some students scoring noticeably higher or lower, thematic analysis was used to explore how high- and low-performing students experienced the modular learning approach. Following a thematic analysis of the selected students' reflections, seven main themes emerged, each with related sub-themes that emphasized the similarities and differences between HPSs and LPSs. These themes encompass collaborative learning, resource use, problem-solving strategies, perceived benefits of the modality, aspects for retention or improvement, challenges encountered, and support mechanisms. The themes, sub-themes, and representative quotes facilitate a comparison of HPS's and LPS's experiences with modular mathematics learning.

Table 3. High-performing and low-performing student experiences in modular learning.

Theme	**Sub-Themes**	**High-Performing Students (HPS)**	**Low-Performing Students (LPS)**
Collaborative Learning	Group Discussions Peer Support	“We collaborated with groupmates and other groups and also the teacher to help answer our problems.” (H1) “If it was confusing, I'd search it up or ask one of the smart kids.” (H5)	(Every math period, my groupmates and I would immediately gather together and start working on the modules.)” (L7) “I asked help from my groupmates at first then answered the rest on my own.” (L1)
Use of Resources	Module-based Learning Use of External Tools	“There were examples in the module. We just followed what was done in the examples.” (H4) “I solved the problems by searching for online resources that would help me comprehend the topic.” (H3)	“I just followed the instructions on the modules…” (L1) “Whenever I couldn’t think of a method, I used my phone or apps to help me understand.” (L2)
Problem-Solving Strategies	Pattern Recognition Application of Examples	“I first understand the given examples and the patterns then applied it in the question.” (H6) “Some of the later modules had fewer examples, so solving was challenging.” (H5)	“I used what I learned from the first pages and then applied it in the worksheet.” (L12) “Maybe if the modules have more examples provided and explanations for each step.” (L6)
Benefits of Modality	Visualization and Real-Life Connection Independent Understanding	“In solving real-life problems, I could imagine it more.” (H1) “It made me learn faster since I could just read and not wait how things work.” (H5)	“Real-life examples make me remember the lesson.” (L9) “I learned to answer at home if math period was not enough.” (L12)
Aspects to Retain or Improve	Collaboration and Research Clarity and Engagement	“Team discussions and teacher roaming around should be retained.” (H8) “More discussions from the teacher—it’s just different when the teacher teaches.” (H9)	“Retain the group activity.” (L3) “Some topics need clearer explanation.” (L12)
Challenges Encountered	Difficulty interpreting questions Communication	“Sometimes the questions are a bit tricky.” (H2) “Sometimes my classmates’ explanations are not clear, so I get confused.” (H10)	“I don’t understand some topics and there are not enough examples.” (L12) “We don’t always finish because we talk too much in group.” (L7)
Support Mechanisms	Teacher Guidance Peer and Media Support	“Our teacher roamed around to help students and guide them in the lessons.” (H8) “The internet is an accessible tool for learning.” (H3)	“I asked help from my teacher when I didn’t understand.” (L8) “My groupmates and classmates helped me overcome challenges.” (L7)

4.3.1. Collaborative learning

Both groups demonstrated collaborative learning, however, with different functions and underlying learning orientations.

For HPSs, collaboration functioned primarily as a verification-oriented and refinement mechanism, where students used peer interaction to validate reasoning and refine independently constructed solutions, while most students (10) used peer discussion to compare answers and clarify concepts. About seven students combined independent and collaborative work, with a few (5) using it to interpret module examples and prior knowledge. In contrast, LPSs exhibited scaffold-dependent collaboration, where they relied primarily on peers for procedural guidance and task completion, with the majority (10) relying on step-by-step assistance from peers. Only a few (2) students engaged in a reciprocal idea exchange. The result suggests that collaboration in HPSs was confirmatory and cognitively evaluative, whereas in LPSs, it was instructional and support-driven, highlighting a clear shift from peer validation to peer dependency across groups.

Given that the module includes some problem-based activities, Xie et al. [44] found that problem-based learning and collaborative learning are effective ways to encourage students to think creatively, collaborate with others, and solve real-world problems.

4.3.2. Use of resources

Both groups made extensive use of modules, peers, teachers, and digital tools, but there were differences in depth and flexibility.

HPSs demonstrated integrative and self-regulated resource use, with most (9) cross-referencing modules with online materials and prior knowledge and six (6) relying on peers primarily for confirmation. The teacher's input was minimal, according to two HPSs. In contrast, LPSs exhibited sequential and assistance-dependent resource use, with the majority (10) relying on peers for step-by-step guidance and seven (7) LPSs using digital tools for procedural understanding. Teacher assistance was more commonly required, as mentioned by 6 LPS. As such, HPSs functioned as a multi-source independent learner, while LPSs operated within a guided-resource reliance framework, indicating differing levels of self-regulated learning.

These results support the suggestion made by Choycawen et al. [45] that future educational policies should consider the use of printed materials in addition to online platforms, especially in blended learning models.

4.3.3. Problem-solving strategies

Problem-solving strategies further reflected a divergence in cognitive autonomy between groups. HPSs adopted a structured self-regulated problem-solving approach, with the majority (10) completing tasks independently using prior knowledge and patterns from examples before seeking confirmation. While verification by peers and digital resources was also common among 9 HPSs. However, LPSs demonstrated assistance-driven problem-solving, with the majority (9) relying on step-by-step peer guidance and using online tools to model solutions. Only a few (3 LPSs) tried independent solutions first. The results imply that HPSs relied on internal cognitive structuring and post-solution verification, while LPSs depended on external scaffolding for solution construction, highlighting a contrast in problem-solving autonomy.

In general, students demonstrated that examples and patterns were not only ways to answer problems but also ways to enhance their confidence and develop their own strategies to solve them. Students should be provided with learning modules that support independent learning and serve as essential resources for solving the problems assigned by the teacher [46].

4.3.4. Benefits of modality

Both groups perceived benefits in modular learning, but the nature of these benefits reflected different learning orientations. HPSs emphasized autonomy-enhancing benefits, particularly flexibility, autonomy, and mastery development, with the majority (10) focusing on self-paced learning and repeated practice. Additionally, students with higher independence suggest enhanced mathematical literacy [47]. While all LPSs (12) emphasized structure-dependent benefits, particularly accessibility and gradual understanding, the majority of them (9) preferred extended time and peer/teacher support. HPSs benefited from independent learning enhancement, whereas LPSs benefited from structured support and guided learning progression. This finding implies that modular learning should balance autonomy for HPSs with structured scaffolding for LPSs.

4.3.5. Aspects to retain or improve

Students expressed their opinions about shared and group-specific priorities for instructional improvement. The majority of the HPSs (10) prioritized retaining collaboration, resource access, and brief teacher clarification, while 5 of them expressed improving the clarity of the module and its examples. On the other hand, 11 LPSs emphasized retaining teacher guidance, group support, and flexible pacing while strongly advocating for more examples, clearer explanations, and structured scaffolding. Generally, HPSs prioritized the enrichment of learning resources, whereas LPSs focused on instructional clarity and support structures. According to their reflections, these students want a well-rounded learning experience that includes collaborative work, clear explanations, and active teacher involvement to make mathematical concepts enjoyable and simple for everyone.

4.3.6. Challenges encountered

The nature of challenges differed significantly between groups in frequency and complexity. HPSs experienced episodic and self-resolved challenges, with the majority (10) occasionally confused and experiencing minor time-related issues that they resolved using available resources. LPSs experienced recurring comprehension and procedural difficulties, with the majority (9) struggling to understand concepts and require assistance, while 8 reported issues related to time management and instruction. Thus, HPS challenges were manageable and self-resolved, whereas LPS challenges were recurring and required support.

4.3.7. Support mechanisms

Support systems were critical in helping students overcome the challenges of learning mathematics in modules. Support systems played distinct functional roles in each group. Both groups used support systems, but they served different functions. Among HPSs, 10 relied primarily on peers, 8 on digital tools, and 6 on teachers to confirm and refine their answers, which functioned primarily as verification and refinement mechanisms. In contrast, among LPSs, 12 relied heavily on peers, 10 on digital tools, and 8 on teacher support for step-by-step instruction and task completion, serving as primary scaffolding structures and guiding students through solution construction. As a result, support mechanisms operated as confirmatory tools in HPS and instructional scaffolds in LPSs, reinforcing a functional difference.

5. Discussions

5.1. Student performance outcomes in modular learning

The posttest results indicate moderate conceptual attainment following exposure to modular learning, suggesting that students were generally able to engage with tasks involving application and reasoning. This result may be linked to the modular-based approach, which has been reported as a potentially effective educational approach in comparison to traditional teaching methods and enables learners to advance at their own pace [48].

However, the uneven distribution of scores, particularly the concentration around average performance and the presence of lower-end variation, imply that students did not benefit from the modality in the same way. This pattern suggests that engagement with modular tasks alone may not be sufficient to ensure consistent conceptual understanding across learners. Rather than reflecting the effectiveness of the modality, the variation in performance may be more strongly associated with differences in prior knowledge, self-regulation, and access to academic support during independent learning. This interpretation is consistent with the findings of Dargo and Dimas [49], who reported a decline in learners' academic performance following the implementation of MDL, highlighting the challenges students face when support structures are limited.

These findings complicate common assumptions that modular learning inherently promotes equitable learning outcomes. Consistent with studies on self-paced learning, the results suggest that modular approaches may unintentionally widen existing learner disparities by favoring students who already possess stronger learning autonomy and metacognitive skills. In this sense, modular learning appears less as a universally effective educational approach and more as a context-dependent learning structure whose success is mediated by the quality of scaffolding and students' readiness for independent learning. Without sufficient instructional support, students may complete tasks procedurally while still experiencing difficulties in deeper conceptual consolidation.

5.2. Student perceptions of modular learning

Student perceptions suggest generally positive affective responses toward modular learning, particularly in terms of flexibility, autonomy, and pacing. Consistent with SDL literature [50], students appeared to value the opportunity to control task completion and manage learning at their pace. However, these positive perceptions should be interpreted cautiously. While students viewed the modality as flexible and compatible with their learning preferences, lower ratings related to conceptual difficulty and real-world application indicate that perceived accessibility did not necessarily translate into deeper mathematical understanding. The finding suggests that positive engagement alone may be insufficient for conceptual consolidation, particularly when learners are expected to process abstract mathematical ideas independently with limited instructional mediation. Crodua [51] reported similar observations, noting that confidence and self-efficacy in modular environments do not always correspond to strong conceptual mastery.

The findings further imply that modular learning may support procedural fluency and learner independence more readily than higher-order conceptual transfer. Students may become comfortable navigating tasks and completing activities without fully internalizing underlying mathematical relationships. Such tension highlights a potential limitation of self-paced modular approaches, particularly for learners requiring stronger cognitive scaffolding. Consequently, modular learning should not be viewed as inherently effective across all learning dimensions but rather as a modality whose success depends heavily on the quality of feedback, contextualized tasks, and structured teacher support. In this regard, Cortes et al. [52] revealed that modular learning participants encountered challenges in self-learning the materials, particularly in the absence of teacher guidance.

The relationship between positive perceptions and stronger performance among some students may therefore reflect differences in learner autonomy and self-regulation rather than the modality alone.

5.3. Comparative insights between HPSs and LPSs

By comparing the experiences of HPSs and LPSs, the study reveals that while the modality supports engagement, collaboration, and SDL, it also exposes disparities in conceptual understanding and self-regulation. Consistent with Bautista [53], self-paced learning appeared more beneficial for HPSs, while the findings also support Mallillin et al. [54], who stressed the need for additional examples and guidance for struggling learners. However, the findings suggest that modular learning does not function uniformly across learner groups. Rather than independently promoting conceptual development, the modality appears to amplify differences in learner autonomy, prior knowledge, and access to support systems. These findings may explain why HPSs were able to use modules as tools for refinement and cognitive regulation, whereas LPSs relied more heavily on procedural assistance and external scaffolding.

Qualitative findings further reinforce this distinction. Although both groups valued collaboration, HPSs primarily used peer interaction to validate reasoning and extend understanding, while LPSs depended on collaboration for clarification and task completion. These patterns align with Foster et al. [55] and Dagdag and Calimag [56] regarding the role of peer interaction in mathematics learning; however, the findings also suggest that collaboration may operate differently depending on students' cognitive readiness and confidence. HPSs demonstrated metacognitive behaviors such as pattern recognition and integration of prior knowledge [57], whereas LPSs exhibited procedural dependence, supporting earlier findings on the need for structured scaffolding among lower-achieving learners [58]. Thus, modular learning may be more effective when paired with differentiated learning [59] support rather than implemented as a uniformly independent learning approach.

5.4. Implications and limitations

The findings emphasize the importance of teacher facilitation, peer collaboration, and resource accessibility in maximizing the benefits of modular learning. Moreover, the study contributes empirical evidence supporting the integration of self-directed and collaborative learning elements in mathematics education, aligning with constructivist and learner-centered frameworks. In practical terms, it helps teachers improve modules, break down difficult tasks, and ensure that all students have the same chances to learn. In practical terms, the results point out that modular learning appears to be beneficial to help students learn math in a way that is independent and meaningful. Teachers should integrate formative feedback, scaffolded examples, and collaborative opportunities to support HPSs and LPSs. Additional innovations, including technology-enhanced or gamified modules, may improve engagement and offer adaptive feedback to bolster motivation and conceptual comprehension. However, comparing HPSs and LPSs shows that modular learning should not be designed in a uniform way but at differentiated levels of task support so that learners can move gradually from procedural understanding to conceptual reasoning.

The research design limits the study. The one-group posttest-only approach, which does not include a pretest, prevents measurement of intervention-related learning gains, while the lack of a comparison group limits causal inferences. Furthermore, the single cohort, single-quarter scope, and restricted content coverage limit generalizability. In future studies, researchers could use longitudinal or mixed-method approaches to examine how sustained exposure to modular learning influences motivation, self-regulation, and conceptual transfer.

6. Conclusions

My objectives and findings suggest that modular learning in mathematics may be associated with student engagement, SDL, and conceptual performance at a moderate level of mastery. The average scores suggest that most students developed a satisfactory understanding of the lessons, though variability in outcomes appears to be linked to differences in prior knowledge, learning strategies, and available support. Peer collaboration plays a supportive role as a learning mechanism, as the approach is associated with a supportive and motivating environment. HPSs tended to demonstrate deeper conceptual engagement and independent strategy use, while LPSs relied more on procedural assistance and collaborative clarification, which signifies that they require differentiated scaffolding. Nevertheless, my results should not be interpreted as evidence of the causal effectiveness of modular learning, as they are descriptive and exploratory. Rather, they offer a preliminary comprehension of the manner in which students interact with and perform in this modality within the specific context of the study.

The results indicate that modality also links with collaboration, motivation, and confidence; however, deficiencies persist in enhancing conceptual depth and practical application. These results highlight the importance of refining learning materials, integrating stronger scaffolding, and balancing independence with guidance to maximize the benefits of modular learning in mathematics. Continued innovation in design, such as integrating feedback mechanisms and contextual problem-solving activities, may correlate with SDL and students' mathematical understanding.

Use of Generative-AI tools declaration

The author intends to disclose the utilization of ChatGPT and Quillbot in the writing of this paper. The tools were employed to enhance the paper's coherence, language, and grammar. The paper continues to accurately reflect the authors' intellectual contributions and work.

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Conflict of interest

There are no conflicts of interest that require disclosure.

Ethics declaration

The school administration supported and promoted the conduct of action research among teachers. Prior to the implementation of modular learning, students were briefed on the purpose and nature of the study. They were again informed during the administration of the Google Forms survey, which aimed to gather their perceptions and experiences with modular learning. Participation in the survey was voluntary, and the confidentiality of responses was ensured. Throughout the conduct of the study, the researcher gave utmost priority to the safety and welfare of the students.

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