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Developing a content-differentiated mathematics teaching module for vocational high school students: Validity, practicality, and effectiveness

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ABSTRACT

The increasing diversity of students' learning readiness, interests, and learning profiles requires mathematics instructional materials that support differentiated learning in vocational education. However, teaching modules specifically designed to facilitate content differentiation remain limited. Unlike conventional mathematics modules that primarily provide uniform instructional content, the module developed in this study explicitly incorporates content differentiation to accommodate variations in students' learning readiness, interests, and learning profiles within vocational education settings. This study aimed to develop and validate a content-differentiated mathematics teaching module that is valid, practical, and effective for vocational high school students. A Research and Development (R&D) approach employing the ADDIE instructional design model (analysis, design, development, implementation, and evaluation) was adopted. The module was evaluated through expert validation involving material, media, and language specialists, while its practicality was assessed using teacher and student response questionnaires. Effectiveness was examined through pretest–posttest achievement data. The findings indicated that the developed module achieved a very high level of validity, with material, media, and language validity scores of 87.47%, 90.00%, and 83.33%, respectively. The module was also perceived as highly practical by teachers (93.65%) and students (87.54%). Furthermore, the implementation of the module significantly improved students' mathematics achievement, as reflected by the increase in the mean score from 64.52 (pretest) to 87.65 (posttest) ($p < .001$). These findings demonstrate that the proposed module provides an effective instructional resource for implementing content differentiation in heterogeneous mathematics classrooms and offers practical support for promoting adaptive and inclusive learning in vocational high schools.

INTRODUCTION

Mathematics education provides an important foundation for students' intellectual and cognitive development because it contributes to the development of logical, analytical, critical-thinking, and problem-solving skills that are essential for everyday life and readiness to meet the demands of 21st-century careers (Cuoco et al., 1996; Midgett & Eddins, 2001; OECD, 2019; Schoenfeld, 2016). In Indonesia, mathematics is taught in stages from elementary school to university as part of a systematic effort to build students' higher-order thinking competencies (Laurens et al., 2017). Conceptually, mathematics is understood as a complex discipline because it involves the coordination of various fundamental abilities, such as number sense, symbolic processing, working memory, visuospatial capacity, and logical reasoning, which interact during the problem-solving process (Dehaene, 2011; Geary, 2011; Karagiannakis et al., 2014; Swanson & Beebe-Frankenberger, 2004). Several studies have also confirmed that weaknesses in one or more of these abilities can contribute to difficulties in mathematics learning and poor academic performance on reasoning and problem-solving tasks (Geary, 2011; Midgett & Eddins, 2001; Peng et al., 2016; Swanson, 2011). Therefore, mathematics education is oriented not only toward mastering procedures and algorithms but also toward developing cognitive structures and thinking strategies that support meaningful and sustainable learning (Cuoco et al., 1996; Midgett & Eddins, 2001; Schoenfeld, 2016).

Current conditions indicate that mathematics education faces complex challenges, particularly those related to the diversity of student characteristics that have not been fully accommodated in instructional practices. One major challenge is the heterogeneity of students' initial abilities, learning experiences, sociocultural backgrounds, interests, and learning styles, which has not been systematically integrated into instructional designs (Cardino & Ortega-Dela Cruz, 2020; Jelatu et al., 2019; Mulwa, 2015). This condition is exacerbated by the continued dominance of a one-size-fits-all approach to mathematics instruction in many contexts, in which instructional strategies are applied without adequately considering individual student differences (Hiebert & Grouws, 2007; Tomlinson, 2014).

Research shows that failure to accommodate diverse student characteristics in instruction may exacerbate achievement gaps and reduce students' motivation and engagement in mathematics learning (Boaler et al., 2000; Ginsburg et al., 2008). Furthermore, other studies confirm that instruction that is not responsive to students' individual needs tends to hinder the development of critical-thinking skills and a deeper understanding of mathematical concepts (Darling-Hammond et al., 2020; Van de Walle et al., 2014). Therefore, differentiated learning strategies and more adaptive pedagogical approaches are needed to address students' varying needs and maximize their potential in mathematics (Tomlinson & Moon, 2013).

The diversity of student characteristics was also evident at Santo Aloysius Vocational High School, Manggarai Regency, East Nusa Tenggara. A preliminary assessment was conducted with 30 Grade 10 students to identify variations in their learning readiness and learning preferences. Students' learning readiness was identified through an initial diagnostic assessment of basic arithmetic skills and classified into three levels: proficient, moderately proficient, and less proficient. The assessment results showed that 7 students were classified as proficient, 10 as moderately proficient, and 13 as less proficient, indicating considerable variation in students' prior mathematical abilities and learning readiness.

In addition, students' learning preferences were identified through preliminary classroom observations. The results showed that 43.3% of students preferred learning through reading materials or visual presentations, 26.7% through listening to explanations, and 30.0% through discussions and practical activities with peers. These preliminary assessments were intended to identify students' instructional needs rather than to provide standardized psychometric classifications; therefore, no standardized learning-style instrument was employed. These findings demonstrate considerable heterogeneity in students' learning readiness and learning preferences, highlighting the need for instructional materials that can adapt mathematical content to students' diverse learning needs.

This phenomenon has implications for teachers as learning leaders who may experience difficulties in delivering learning materials appropriate to the individual needs of students in heterogeneous classrooms (Subban, 2006; Tomlinson et al., 2003). Classroom observations indicated that the Grade 10 mathematics teacher at Santo Aloysius Vocational High School experienced difficulties in delivering learning materials to a heterogeneous class. Teachers must strive to meet the needs of individual students but often experience difficulty providing individualized attention. As a result, some students may fall behind, while others may become disengaged. This is a concern because it may hinder student development and reduce students' interest in learning and engaging with mathematics.

Several factors may contribute to these difficulties, including limited flexibility and responsiveness in implementing Indonesia's new curriculum, which is intended to accommodate diverse student needs in the classroom. Teachers may lack sufficient opportunities to plan and implement instruction that accommodates diverse student populations because of time constraints, limited resources, and insufficient institutional support (Saigar & Jamaludin, 2025). Another factor is the challenge of developing content that meets students' varying levels of understanding and ability (Sachdeva & Eggen, 2021). Learning approaches and activities that do not support content or subject-matter differentiation can also make it difficult for teachers to address students' diverse needs (Goyibova et al., 2025). These findings indicate that instructional resources capable of accommodating differentiated learning, including teaching materials and lesson plans referred to as teaching modules in the Kurikulum Merdeka, remain limited. This finding is supported by an interview with a Grade 10 mathematics teacher at Santo Aloysius Vocational High School, who reported that teaching modules or lesson implementation plans emphasizing differentiation, particularly content differentiation in heterogeneous classrooms, remain limited.

Differentiated learning, whether in terms of process, content, or product, represents an important approach for addressing student diversity in heterogeneous classrooms. This approach allows students to learn material based on their talents, interests, readiness levels, initial abilities, and special needs (Tomlinson, 2001). Teachers can tailor materials, activities, assignments, and assessments to students' characteristics, thereby making instruction more inclusive and maximizing learning opportunities (Goyibova et al., 2025; Marlina et al., 2023; Reis et al., 2011; Stavrou & Koutselini, 2016). Differentiation does not mean completely individualized learning, but rather adapting strategies so that heterogeneous students can learn effectively.

Previous studies have demonstrated the potential of mathematics modules developed using various instructional approaches to improve learning outcomes. For example, Kintoko and Jana (2019) developed a culture-based mathematics module, Taufikurrahman et al. (2021) developed a module based on meaningful learning, Lumbantoruan and Ditasona (2024) developed a mathematics module incorporating small-group discussion, and Paguirigan and Paguirigan (2024) employed the 5E learning model in mathematics module development. Although these studies provide important evidence regarding the effectiveness of structured mathematics modules, their primary emphasis has been on particular instructional models, learning activities, or achievement outcomes rather than on systematically differentiating mathematical content according to variations in students' readiness, interests, and learning profiles.

Meanwhile, research on differentiated instruction has demonstrated its potential for addressing student diversity (Deunk et al., 2018; Marlina et al., 2023; Pozas et al., 2020; Smale-Jacobse et al., 2019), but empirical studies translating these principles into validated mathematics teaching modules for vocational high school contexts remain limited. Thus, a gap exists between research on mathematics module development and research on differentiated instruction. The present study addresses this gap by integrating content differentiation principles into a mathematics teaching module specifically designed for heterogeneous vocational high school classrooms and evaluating its validity, practicality, and effectiveness through the ADDIE development process.

The development of content-differentiated learning modules is important given the limited availability of modules and lesson plans at Santo Aloysius Vocational High School in Ruteng that support heterogeneous classrooms. These modules are expected to support teachers in designing and implementing learning that is responsive to differences in student readiness levels, interests, and learning styles, thus enabling more effective mathematics instruction. Therefore, this study aims to develop and validate a content-differentiated mathematics teaching module for vocational high school students using the ADDIE model. Specifically, the study evaluated the module's validity, practicality, and effectiveness in supporting adaptive and inclusive mathematics learning within heterogeneous classrooms. Accordingly, this study addressed the following research questions: (1) To what extent is the developed content-differentiated mathematics teaching module valid in terms of content, media, and language? (2) To what extent is the developed module practical based on teacher and student responses? (3) To what extent is the developed module effective in improving vocational high school students' mathematics achievement?

METHOD

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five sequential phases: analysis, design, development, implementation, and evaluation (Spatioti et al., 2022; Szabo, 2022). The ADDIE model was selected because it provides a systematic framework for designing, developing, implementing, and evaluating instructional materials to ensure their validity, practicality, and effectiveness. The study was conducted at Santo Aloysius Vocational High School during the second semester of the 2023/2024 academic year. Participants included two subject-matter experts, two media experts, one language expert, one mathematics teacher, and Grade 10 students.

The implementation was conducted in two stages. First, a limited trial involving 15 students was conducted to obtain formative feedback on the usability of the module and the implementation of content differentiation. Following revisions based on the limited trial, a field trial was conducted with 30 Grade 10 students selected through simple random sampling using a lottery technique. The 30-student sample was considered adequate for the field-testing stage of this developmental study because the primary purpose was to evaluate the practicality and preliminary effectiveness of the developed module within its intended classroom context rather than to generalize the findings to a broader population. Data were collected using expert validation sheets, teacher and student response questionnaires, and mathematics achievement tests administered before and after the implementation of the developed module.

The validity of the teaching module was assessed using percentage-based expert judgment. This approach was selected because the validation process focused on the formative evaluation of the module's overall feasibility across content, media, and language dimensions during the development stage. Expert ratings were summarized relative to the maximum possible score and interpreted according to predetermined validity categories. Established item-level content validity indices, such as Aiken's V and the Content Validity Index (CVI), were not applied because the validation procedure focused on overall module feasibility rather than item-level agreement. Specifically, language feasibility was evaluated by one language expert using the same percentage-based expert judgment approach. Because this evaluation involved a single expert, the resulting score should be interpreted as an expert assessment of the module's linguistic feasibility rather than as a measure of inter-expert agreement. The validity percentage was calculated using Equation (1):

$$V = \frac{\sum x}{\sum x_i} \times 100\%\ldots(1)$$

where V represents the percentage of module validity, $\sum x$ is the total score assigned by the experts, and $\sum x_i$ is the maximum possible score. Higher percentages indicate more favorable expert assessments of the feasibility of the developed module. The practicality of the teaching module was assessed using percentage analysis of teacher and student response scores. This approach was used to determine the extent to which the module was perceived as usable and implementable in the intended classroom context by comparing the obtained response scores with the maximum possible scores. The practicality percentage was calculated using Equation (2):

$$P = \frac{\sum TSe}{\sum TSh} \times 100\%\ldots(2)$$

where P represents the percentage of module practicality, $\sum TSe$ represents the total response score obtained from students or teachers, and $\sum TSh$ represents the maximum possible total response score. The resulting percentages were interpreted according to the practicality categories presented in Table 1.

Table 1. Validity and Practicality Categories of the Teaching Module

Score Interval (%)	Validity Category	Practicality Category
80% < score ≤ 100%	Very Valid	Very Practical
60% < score ≤ 80%	Valid	Practical
40% < score ≤ 60%	Fairly Valid	Fairly Practical
20% < score ≤ 40%	Less Valid	Less Practical
0% < score ≤ 20%	Invalid	Not Practical

The effectiveness of the teaching module was evaluated using the normalized gain (N-gain) score and a paired-samples t-test. The N-gain score was used to determine the magnitude of improvement in students' mathematics achievement following instruction using the content-differentiated mathematics teaching module. The N-gain score was calculated using Equation (3):

$$N\text{-}gain = \frac{NPo - NPr}{N_i - NPr} \ldots (3)$$

where NPo represents the posttest score, NPr represents the pretest score, and N_i represents the maximum possible score. The resulting N-gain values were interpreted according to the categories presented in Table 2.

Table 2. N-gain Categories

Interval	Category
N-gain > 0.7	High
0.3 ≤ N-gain ≤ 0.7	Medium
N-gain < 0.3	Low

A paired-samples t-test was subsequently conducted to determine whether the difference between students' pretest and posttest mathematics achievement scores was statistically significant. Prior to conducting the paired-samples t-test, the normality of the difference scores (posttest − pretest) was assessed using the Shapiro–Wilk test. The results indicated that the difference scores did not significantly deviate from normality ($p > .05$), supporting the use of the paired-samples t-test. Statistical significance was determined at $p < .05$. The paired-samples t-test was calculated using Equation (4):

$$t = \frac{\bar{D}}{SD/\sqrt{n}} \ldots (4)$$

where t represents the calculated t value, $\bar{D}$ represents the mean difference between posttest and pretest scores, SD represents the standard deviation of the difference scores, and n represents the number of paired observations. Statistical analyses were performed using SPSS version 16.0.

RESULTS AND DISCUSSION

The content differentiation-based mathematics teaching module was developed using the ADDIE instructional design model, which consists of five sequential phases: analysis, design, development, implementation, and evaluation. During the analysis phase, curriculum requirements, intended learning outcomes, and students' learning needs were examined to identify instructional problems and determine the necessity of differentiated learning materials. The analysis revealed that Grade 10 mathematics instruction required teaching materials capable of accommodating students with diverse levels of readiness, interests, and learning profiles.

During the design phase, the teaching module was systematically structured using clear typography, visually appealing layouts, and hierarchically organized learning content progressing from basic to advanced concepts. Content differentiation principles were integrated into the module to enable students to access learning materials according to their readiness levels and learning preferences. The development phase involved preparing comprehensive learning materials, including conceptual explanations, worked examples, and progressively challenging practice exercises that reflected students' diverse learning needs. The completed module subsequently underwent expert validation and revision before classroom implementation.

During the implementation phase, the module was initially piloted with 15 students to obtain formative feedback regarding its usability and the implementation of content differentiation. After necessary revisions, the final version was implemented with 30 Grade 10 students over one academic semester. Student participation, engagement, and classroom activities were continuously monitored throughout the implementation process.

Finally, the evaluation phase examined the quality of the developed module through validity, practicality, and effectiveness assessments. Validity was evaluated by subject-matter, media, and language experts, while practicality was assessed through teacher and student responses. Module effectiveness was determined by comparing students' mathematics achievement before and after implementation using pretest and posttest scores.

Content Validity Results

Content validity was evaluated by two subject-matter experts across four dimensions: alignment between learning objectives and learning outcomes, clarity of learning phases, differentiated learning, and content differentiation. As presented in Table 3, all evaluated aspects achieved percentages above 80%, indicating a very valid level of content quality. Among the evaluated dimensions, differentiated learning received the highest score (90.00%), suggesting that the module successfully incorporated differentiated instructional principles into mathematics learning. Although clarity of the learning phases received the lowest percentage (82.81%), it remained within the very valid category, indicating that only minor revisions were required. Overall, the average content validity score of 87.47% confirms that the developed module possesses strong instructional quality and is appropriate for classroom implementation.

Table 3. Content Expert Validation Results

Assessment Aspect	Score 1	Score 2	Average	Max Score	Percentage (%)	Category
Alignment of learning objectives with learning outcomes	20	23	21.50	24	89.58	Very Valid
Clarity of learning phases in each stage	28	25	26.50	32	82.81	Very Valid
Differentiated learning	18	18	18.00	20	90.00	Very Valid
Content differentiation in the module	18	17	17.50	20	87.50	Very Valid
Average					87.47	Very Valid

Media Validity Results

Media validity was assessed by two media experts based on four aspects: media usability, message attractiveness, effectiveness and efficiency of media use, and student engagement through media utilization. As shown in Table 4, all assessed indicators were classified as very valid, with an overall average score of 90.00%. The highest score was obtained for media usability (92.50%), indicating that the module was considered easy to use and visually appropriate for learning activities. Although student engagement through media utilization received the lowest score (87.50%), it remained within the very valid category. These findings demonstrate that the developed module effectively integrates instructional design principles with user-friendly learning media.

Table 4. Media Expert Validation Results

Assessment Aspect	Score 1	Score 2	Average	Max Score	Percentage (%)	Category
Demonstrating skills in media usage	17	20	18.50	20	92.50	Very Valid
Producing interesting messages	19	17	18.00	20	90.00	Very Valid
Using media effectively and efficiently	18	18	18.00	20	90.00	Very Valid
Involving students in media utilization	17	18	17.50	20	87.50	Very Valid
Average					90.00	Very Valid

Language Validity Results

Language validity was evaluated by one language expert, focusing on language appropriateness, communicativeness, sentence simplicity, and dialogic interaction. The findings presented in Table 5 indicate that the module achieved an overall language validity score of 83.33%, which falls within the very valid category. Compliance with Indonesian language conventions and simplicity of sentence structure both received the highest percentage (87.50%), reflecting the readability of the module. Although the communicative language aspect received a relatively lower score (75.00%), it remained within the valid category, suggesting that only minor linguistic refinement was necessary. Overall, the language used in the module was considered suitable for vocational high school students.

Table 5. Language Expert Validation Results

Assessment Aspect	Score	Max Score	Percentage (%)	Category
Compliance with proper Indonesian language rules	7	8	87.50	Very Valid
Communicative language	9	12	75.00	Valid
Simplicity of sentence structure	7	8	87.50	Very Valid
Dialogic and interactive language	10	12	83.33	Very Valid
Average			83.33	Very Valid

Although the overall language validity was categorized as very valid, the communicative language dimension received a comparatively lower score (75.00%) than the other dimensions. This finding suggests that some explanations or instructional directions in the module may still require refinement to ensure that mathematical concepts are communicated in a more accessible and learner-friendly manner. This aspect is particularly important in differentiated instruction because differences in students' readiness levels may also influence how effectively they interpret instructional language. Therefore, linguistic clarity and communicativeness should remain important considerations when differentiated mathematics materials are implemented in heterogeneous classrooms.

Among the dimensions of student responses, content differentiation received the lowest score (82.25%), although it remained within the very practical category. This comparatively lower rating may indicate that adapting to different forms or levels of mathematical content requires greater adjustment by students than engaging with the module's visual and interactive features. This finding also highlights an important practical consideration: differentiated materials do not necessarily ensure that every student will immediately recognize or effectively use the learning pathways provided. Teacher guidance may therefore remain necessary to help students select and engage with content appropriate to their learning needs.

Practicality Test Results: Teacher Responses

Teacher responses demonstrated a highly positive perception of the developed module. As presented in Table 6, all evaluated aspects exceeded 90%, resulting in an overall practicality score of 93.65%. The highest score was observed for the alignment between learning objectives and learning outcomes (95.83%), indicating that teachers considered the module well aligned with curriculum expectations. Likewise, the implementation of differentiated learning and content differentiation received consistently high evaluations.

The positive practicality evaluation suggests that integrating content differentiation into structured mathematics teaching materials can be manageable for teachers and accessible to students in heterogeneous classrooms. This finding is consistent with previous research showing that differentiated instruction can support diverse student needs by adapting instructional content and learning opportunities (Marlina et al., 2023; Pozas et al., 2020). At the same time, the present study extends previous research on mathematics module development (Lumbantoruan & Ditasona, 2024; Paguirigan & Paguirigan, 2024) by explicitly embedding content differentiation based on students' readiness and learning needs within the module design.

Table 6. Teacher Response Results

Assessment Aspect	Score	Max Score	Percentage (%)	Category
Alignment of learning objectives with outcomes	23	24	95.83	Very Practical
Clarity of learning phases	30	32	93.75	Very Practical
Differentiated learning	18	20	90.00	Very Practical
Content differentiation in the module	19	20	95.00	Very Practical
Average			93.65	Very Practical

Student responses further confirmed the practicality of the module, with an overall practicality score of 87.54%. Presentation attractiveness and interactivity received the highest rating (95.50%), whereas content differentiation received the lowest rating (82.25%), although both remained within the very practical category. The comparatively lower score for content differentiation suggests that students may require additional teacher guidance to effectively navigate differentiated content according to their learning needs.

Practicality Test Results: Student Responses

Student responses were collected across four aspects: content, content differentiation, presentation attractiveness and interactivity, and language use. The results are presented in Table 7.

Table 7. Student Response Results

Assessment Aspect	Score	Max Score	Percentage (%)	Category
Content	10.13	12	84.42	Very Practical
Content differentiation	9.87	12	82.25	Very Practical
Presentation attractiveness and interactivity	11.46	12	95.50	Very Practical
Language used	10.56	12	88.00	Very Practical
Average			87.54	Very Practical

The lowest percentage was obtained for content differentiation (82.25%), whereas the highest was obtained for presentation attractiveness and interactivity (95.50%). The overall average student response percentage was 87.54%, indicating that the module was very practical.

Effectiveness Test Results

The effectiveness of the developed module was examined using descriptive statistics, normalized gain (N-gain), and inferential statistical analyses. As presented in Table 8, students' mathematics achievement improved substantially following the implementation of the content differentiation-based teaching module. The mean pretest score increased from 64.52 to 87.65 in the posttest. The calculated N-gain value of 0.652 fell within the medium improvement category, indicating a meaningful improvement in students' mathematics achievement following module implementation.

Table 8. Descriptive Statistics of Pretest and Posttest Scores

Test	N	Range	Min	Max	Mean	Std. Dev	Variance
Pretest	30	17	58	75	64.52	2.463	6.537
Posttest	30	19	78	97	87.65	2.729	8.643

Before conducting inferential analysis, assumption testing was performed. The Shapiro–Wilk test indicated that both pretest ($p = .078$) and posttest ($p = .084$) scores were normally distributed (Table 9), satisfying the normality assumption required for parametric testing. Furthermore, the homogeneity test produced a significance value of 0.274, confirming homogeneous score variances between the two datasets.

The paired-sample t-test revealed a statistically significant difference between pretest and posttest scores ($p < .001$), as presented in Table 10. This finding demonstrates that students achieved significantly higher mathematics learning outcomes after using the developed teaching module.

Taken together, the moderate N-gain value and the statistically significant improvement in students' mathematics achievement provide preliminary evidence that the content-differentiated mathematics teaching module has potential to support mathematics learning. However, because the study employed a one-group pretest–posttest design without a comparison group, the observed improvement should not be interpreted as definitive evidence of a causal effect of the module.

Table 9. Normality Test of Pretest and Posttest Data

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Mathematics Achievement	Pretest	.143	30	.032	.863	30	.078
	Posttest	.127	30	.061	.856	30	.084

The normality test results showed significance values of .078 and .084, both greater than .05, indicating that the pretest and posttest scores did not significantly deviate from normality. Therefore, the data were considered suitable for parametric analysis using a paired-samples t-test. The homogeneity test result ($p = .274$) indicated that the variances of the pretest and posttest scores did not differ significantly. This supports the validity of the paired sample t-test results.

Table 10. Paired Sample t-test

Comparison	Pretest Mean	Posttest Mean	Mean Improvement	N	*df*	Significance
Pretest–Posttest	64.52	87.65	23.13	30	29	$p < .001$

The results indicate that students' mean mathematics achievement score increased from 64.52 on the pretest to 87.65 on the posttest, representing a mean improvement of 23.13 points. The paired-samples t-test indicated that the difference between pretest and posttest scores was statistically significant ($p < .001$). Together with the N-gain value of 0.652, these findings demonstrate a meaningful improvement in students' mathematics achievement following implementation of the content-differentiated mathematics teaching module.

CONCLUSION

The present study successfully developed and validated a content-differentiated mathematics teaching module for vocational high school students using the ADDIE instructional design model. The developed module demonstrated high validity in terms of content (87.47%), media (90.00%), and language (83.33%), while also achieving high practicality, as reflected in positive evaluations from teachers (93.65%) and students (87.54%). Furthermore, students demonstrated a significant improvement in mathematics achievement following the implementation of the module, as indicated by a moderate N-gain score (0.652) and a statistically significant difference between pretest and posttest scores ($p < .001$). These findings provide preliminary evidence of the module's effectiveness within the context of this developmental study. From a theoretical perspective, this study extends the application of content differentiation in vocational mathematics education by demonstrating that instructional materials designed according to students' diverse readiness levels, interests, and learning profiles can support differentiated instruction in heterogeneous classrooms. These findings contribute to the growing body of evidence supporting adaptive instructional approaches to enhance student engagement and mathematics learning outcomes

Practically, the developed module provides teachers with a structured and implementable instructional resource for designing adaptive mathematics learning experiences. The findings also have implications for curriculum developers and educational policymakers by illustrating how differentiated instructional materials can support inclusive and learner-centered mathematics education in vocational high schools. This study is subject to several limitations. The effectiveness of the module was evaluated within a single vocational high school involving a relatively small sample of students, which may limit the generalizability of the findings. Future research should examine the module across multiple vocational high schools with larger and more diverse student populations and employ comparative or experimental designs to strengthen evidence of effectiveness. Longitudinal studies are also recommended to determine whether improvements in mathematics achievement are sustained over time. Further research may compare content, process, and product differentiation and explore digital or AI-assisted modules capable of adapting learning materials to students' readiness and learning progress. Overall, this study indicates that a content-differentiated mathematics teaching module represents a promising instructional innovation for promoting adaptive, inclusive, and learner-centered mathematics education in vocational high school classrooms.

Future research should extend the implementation of the module across multiple vocational high schools with larger and more diverse student populations to examine its generalizability. Longitudinal studies are also needed to determine whether the observed improvements in mathematics achievement are sustained over time. Comparative studies could further examine the relative effectiveness of content, process, and product differentiation in mathematics instruction. In addition, future development may explore digital and AI-assisted differentiated mathematics modules capable of providing more adaptive learning materials based on individual students' readiness and learning progress.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial or non-financial interests that could have appeared to influence the work reported in this paper.

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