



Developing RITME: An AI-Powered Learning Media Based on Mathematical Growth Mindset to Support Quality Education

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Abstract:

The integration of artificial intelligence (AI) into mathematics education offers opportunities to create adaptive, interactive, and learner-centered learning environments. However, digital learning media that simultaneously integrate AI capabilities with Mathematical Growth Mindset principles remain limited. Developing such media is important for supporting meaningful mathematics learning and advancing Sustainable Development Goal 4 (Quality Education). This study aimed to develop RITME (AI-Powered Learning Based on Mathematical Growth Mindset) as an innovative mathematics learning medium that integrates AI-supported learning with Mathematical Growth Mindset principles. This study employed a Research and Development (R&D) approach using the Four-D (4D) development model, consisting of Define, Design, Develop, and Disseminate stages. The development process was conducted up to the Develop stage and involved validity, practicality, and effectiveness testing. Data were analyzed descriptively using percentage scores. RITME achieved very high validity (92.85%), practicality (94.12%), and effectiveness (89.76%). These findings indicate that RITME is a feasible digital learning innovation for supporting adaptive and learner-centered mathematics instruction. Its integration of AI and Mathematical Growth Mindset principles provides a pedagogical contribution to strengthening mathematics learning and supporting the broader goal of achieving SDG 4.

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INTRODUCTION

Educational transformation has become a necessity because technological environments increasingly shape how people learn, work, and participate in society. Quality mathematics education is important because mathematical competence supports reasoning, problem solving, and informed decision making in life. Evidence on sustainable education shows that educational technologies can contribute to SDG 4 by expanding access, personalization, and learning opportunities when implemented appropriately (Costa et al., 2024; AlSagri & Sohail, 2024; Naimah & Prahasti, 2026). Conversely, inadequate adaptation of mathematics education may widen learning inequalities, weaken students' preparedness for technological societies, and limit opportunities. This challenge is especially relevant when digital transformation occurs without pedagogical innovation. Therefore, mathematics learning requires solutions that

combine technological accessibility with meaningful instructional support. Developing learning media that responds to diverse learner needs is consequently important for classroom improvement and advancing inclusive, equitable, and sustainable quality education. This is a shared educational priority.

The development of RITME is grounded in complementary concepts: AI-supported adaptive learning and mathematical growth mindset. Adaptive learning uses systems to adjust learning experiences according to learners' needs, while AI can provide personalization, intelligent assistance, and responsive feedback (Akavova et al., 2023; Gligorea et al., 2023; Sajja et al., 2024). Mathematical growth mindset emphasizes that mathematical abilities can develop through effort, strategies, and learning experiences rather than being permanently fixed. Research shows that mathematical mindset is associated with how students approach mathematical learning and challenges (Im & Park, 2023; Stohlmann & Yang, 2024; Naimah et al., 2026). These concepts are relevant to RITME because AI can provide adaptive instructional support while growth mindset principles can shape students' responses to difficulty, errors, and persistence. Their integration therefore offers a foundation for developing mathematics media that addresses cognitive learning needs and students' dispositions toward mathematical learning.

The need for such integration is evident in the current learning context of Junior High School. Observations and teacher interviews indicated that mathematics instruction remained dependent on presentation media and conventional learning materials, limiting opportunities for interactive and adaptive learning experiences. Students encountered difficulties in geometric sequences, particularly in recognizing patterns, determining ratios, and connecting concepts with contextual problems. At the same time, several students displayed behaviors associated with fixed mathematical beliefs, including reluctance to attempt challenging problems, fear of making mistakes, and limited confidence in explaining solution strategies. These conditions reveal a gap between the theoretical potential of adaptive, student-centered learning and its implementation in the classroom. Without appropriate intervention, difficulties in conceptual understanding and responses to mathematical challenges may persist. Therefore, the context requires a medium that supports conceptual learning while encouraging persistence, reflection, and constructive responses to mathematical difficulty.

RITME needs to be developed because existing mathematics media do not fully address the combined instructional and psychological needs identified in the field. Digital learning resources can improve engagement and provide experiences, yet technology alone does not guarantee adaptive instruction or meaningful student agency. Reviews of AI-supported education emphasize its potential for personalization and adaptive learning, while highlighting the importance of pedagogical design in determining educational value (Demartini et al., 2024; Tan et al., 2025). Similarly, growth mindset research suggests that students' mathematical beliefs require supportive learning environments (van Hoeve et al., 2025; Xu et al., 2025; Prahasti et al., 2026). Thus, a product is needed that moves beyond presenting content and exercises toward integrating intelligent feedback, interactive learning, and mindset-oriented support. RITME addresses this need by combining AI functionality with mathematical growth mindset principles within a supportive learning environment for students effectively.

Previous studies have established the potential of digital and AI-supported technologies for improving learning experiences. AI-powered applications can support engagement, personalization, and interaction, while adaptive learning systems can

respond to differences among learners (Chang et al., 2022; Anapah et al., 2026). Reviews and case studies further indicate that AI can strengthen adaptive learning through personalized support and intelligent instructional processes (Demartini et al., 2024; Kharismasyah et al., 2026). In mathematics education, research has also examined mathematical mindset as an important dimension of students' learning experiences. Studies have investigated mathematical mindset characteristics, measurement, and its relationship with mathematics learning (Saefudin et al., 2023; Evanita et al., 2026). However, these research strands have generally developed along separate pathways: AI research emphasizes technological personalization, whereas mindset research emphasizes learner beliefs and behaviors. This separation leaves an important opportunity for integrated product development opportunities.

The literature also indicates that the relationship between growth mindset and mathematics achievement is not uniformly straightforward. Reviews and intervention research have reported positive possibilities but also emphasized variation across contexts and implementation conditions (Macnamara & Burgoyne, 2023; He et al., 2024). Meanwhile, research increasingly positions AI as a mechanism for student-centered and personalized learning, but emphasizes that responsible educational implementation must address inclusion, ethics, and human agency (Abuhassna et al., 2025; Flores-Viva & García-Peñalvo, 2023; Tang, 2026). These findings reveal two gaps. First, limited research has translated mathematical growth mindset principles into an AI-supported learning product. Second, fewer studies have examined an integrated product that simultaneously targets adaptive learning and students' mathematical dispositions within a junior high school context. RITME responds to these gaps by connecting technological adaptation with mindset-oriented pedagogy rather than treating them as educational interventions effectively.

The state of the art represented by RITME lies in integrating AI-powered adaptive learning and Mathematical Growth Mindset within one interactive mathematics learning medium. Rather than functioning primarily as a digital repository of materials or exercises, RITME is designed as a learning environment combining intelligent feedback, interactive activities, adaptive support, and mindset-oriented learning experiences. Its novelty is therefore not simply the inclusion of AI, but the pedagogical integration of AI functionality with a framework for developing students' mathematical beliefs and responses to challenge. This configuration distinguishes RITME from products emphasizing technological personalization without an explicit mindset dimension and from mindset interventions not embedded within digital learning media. The product consequently offers a combined cognitive-affective approach to mathematics learning, positioning technology as support for conceptual development and learner agency while aligning innovation with the broader aspiration of SDG 4 quality education.

The research problem concerns how an AI-powered learning medium can be developed to address students' mathematical learning needs while supporting a Mathematical Growth Mindset in a junior high school context. The proposed solution is RITME, an interactive learning medium combining adaptive AI-supported features with activities and feedback that encourage persistence, reflection, and constructive responses to mathematical challenges. Accordingly, this study aims to develop RITME for geometric sequences using a Research and Development approach. Specifically, the study seeks to determine the validity of the developed product through expert assessment, examine its practicality based on teacher and student responses, and evaluate its effectiveness in supporting students' achievement of learning objectives.

Through these stages, the study is expected to produce a feasible mathematics learning medium that integrates technological innovation with learner-centered principles and provides a practical contribution to contemporary digital mathematics education.

RESEARCH METHOD

This study employed a Research and Development (R&D) design to develop and evaluate RITME (AI-Powered Learning Based on Mathematical Growth Mindset), an AI-based mathematics learning media designed to support adaptive, interactive, and student-centered learning. R&D was selected because it enables systematic development, validation, revision, and evaluation of educational products (Rahayu, 2025; Lestari & Priantara, 2026). The Four-D (4D) model was adopted because it provides a systematic framework consisting of four stages: Define, Design, Develop, and Disseminate (Harjanto et al., 2023; Indaryanti et al., 2025). Previous studies have also applied the 4D model to develop educational learning media (Ansori et al., 2024; Putri & Priantara, 2026). In this study, development was limited to the Develop stage because the research focused on producing the media and evaluating its validity, practicality, and effectiveness before wider dissemination. The complete development sequence is presented in Table 1.

Table 1. Stages of the Four-D (4D) Development Model

Stage	Activities	Output
<i>Define</i>	Analysis of the curriculum, learner characteristics, learning materials, learning needs, and learning objectives	Specifications of learning media development needs
<i>Design</i>	Preparation of the media design, storyboard, learning materials, user interface, AI features, and research instruments	Initial RITME prototype
<i>Develop</i>	Expert validation, product revision, practicality testing, revision, and effectiveness testing	Final product that is valid, practical, and effective
<i>Disseminate</i>	Dissemination of the developed product	Not conducted in this study

The research was conducted at SMP Negeri 7 Tanjungpinang, using RITME as the research product and geometric sequences as the learning topic. The participants comprised three material experts and three media experts for product validation, three mathematics teachers and 15 students for practicality testing, and 15 students for effectiveness testing. Participants were selected purposively because they were directly relevant to the evaluation of the developed learning media. Expert assessment was used to determine product feasibility, while teacher and student involvement provided information regarding practicality and effectiveness. Expert validation is commonly used in educational media development to evaluate product quality before implementation (Oksila et al., 2025; Suriono & Dewantoro, 2026). The same 15 students participated in effectiveness testing after using RITME to assess achievement of the intended learning objectives. Thus, participant selection was aligned with the development stages and evaluation purposes.

Data were collected through validation sheets, practicality questionnaires, and learning achievement tests. The validation sheets were completed by material and media experts to assess content suitability, language, presentation, graphical design, interactivity, and usability. Practicality questionnaires were administered to mathematics teachers and students after using RITME to assess ease of use, clarity, attractiveness,

efficiency, and usefulness. Learning achievement tests were administered after implementation to assess the effectiveness of RITME in supporting geometric-sequence learning outcomes. The use of validity, practicality, and effectiveness as complementary indicators is consistent with previous learning-media development research (Rohman, 2025; Susiani et al., 2024). The procedures were conducted sequentially, beginning with expert validation and revision, followed by practicality testing and revision, and ending with effectiveness testing. This sequence allowed the product to be evaluated from expert and user perspectives before effectiveness assessment.

Data were analyzed using descriptive quantitative analysis based on percentage scores. Validity analysis used scores from the three material experts and three media experts, while practicality analysis used responses from the three mathematics teachers and 15 students. Effectiveness analysis used students' learning achievement test results after using RITME. Each percentage was calculated by dividing the obtained score by the maximum possible score and multiplying it by 100. The resulting percentages were interpreted according to the criteria presented in Table 2. Percentage-based analysis is commonly used in R&D studies to determine the validity, practicality, and effectiveness of developed learning media (Oksila et al., 2025; Zairi & F, 2026). The validity results determined the feasibility of the content, design, and technical aspects, while practicality reflected ease and usefulness of use. Effectiveness indicated the extent to which RITME supported the intended learning outcomes. These three components determined the overall quality of the developed media.

Table 2. Criteria for Interpreting the Validity, Practicality, and Effectiveness of the Learning Media

Percentage (%)	Achievement Level	Category
81–100	Very High	Very Valid / Very Practical / Very Effective
61–80	High	Valid / Practical / Effective
41–60	Moderate	Fairly Valid / Fairly Practical / Fairly Effective
21–40	Low	Less Valid / Less Practical / Less Effective
0–20	Very Low	Invalid / Impractical / Ineffective

Note: The interpretation criteria were adapted for use in this study.

RESULT AND DISCUSSION

Result

The research findings are presented based on the stages of the Four-D (4D) development model, which comprises Define, Design, Develop, and Disseminate. However, in accordance with the research scope, the development process was limited to the Develop stage; consequently, the findings focus on the needs analysis, media design, and product quality assessment specifically tests of validity, practicality, and effectiveness. The presentation of results for each stage aims to provide a systematic overview of the development process for the RITME learning media (AI-Powered Learning Based on Mathematical Growth Mindset), culminating in a product suitable for use in mathematics instruction. The development outcomes for each stage of the Four-D (4D) model are outlined below.

Define

The Define stage is the initial phase of the Four-D (4D) development model, aimed at identifying and establishing learning needs to serve as the foundation for developing the RITME media (AI-Powered Learning Based on Mathematical Growth Mindset). Five key activities are conducted during this stage: front-end analysis, learner analysis, task

analysis, concept analysis, and the specification of instructional objectives. These analyses are carried out through classroom observations, interviews with mathematics teachers, curriculum document analysis, and the identification of student characteristics at SMP Negeri 7 Tanjungpinang. The results of these analyses form the basis for determining media characteristics, developing content, designing features, and integrating Artificial Intelligence and the Mathematical Growth Mindset approach into the RITME learning media.

Based on the analysis, several issues were identified that serve as the basis for media development. Mathematics instruction remains dominated by the use of simple presentation media and conventional teaching materials, meaning students have not yet experienced interactive and adaptive learning. Furthermore, students struggle to grasp mathematical concepts particularly regarding geometric sequences and exhibit tendencies associated with a fixed mindset, such as easily giving up when faced with challenging problems, lacking confidence in their mathematical abilities, and believing that mathematical aptitude is an innate talent that is difficult to develop. On the other hand, teachers require learning media capable of presenting material in a more engaging manner, providing immediate feedback, and facilitating student-centered learning. A summary of the needs analysis results from the Define stage is presented in Table 3.

Table 3. Results of Needs Analysis at the Define Stage

Analysis Component	Analysis Result	Implication for RITME Development
Front-end Analysis	Mathematics learning is still dominated by the use of simple presentation media and conventional teaching materials, making the learning process less interactive and unable to optimally facilitate students' learning needs.	RITME is developed as an interactive AI-based learning media capable of creating a more engaging, adaptive, and student-centered learning experience.
Learner Analysis	Students experience difficulties in understanding geometric sequence concepts, lack confidence in solving mathematical problems, give up easily when facing challenging tasks, and tend to exhibit a fixed mindset.	RITME integrates the Mathematical Growth Mindset approach, adaptive feedback, and learning activities that encourage students to be more confident, persistent, and active in their learning.
Task Analysis	Students are expected to be able to identify geometric sequence patterns, determine ratios, find the n -th term, calculate the sum of the first n terms, and solve contextual problems related to geometric sequences.	The materials and exercises in RITME are structured progressively from basic concepts to contextual problem-solving with systematically increasing levels of difficulty.
Concept Analysis	The concepts within the geometric sequence material are systematically interconnected and must be learned progressively so that students can achieve a comprehensive conceptual understanding.	The material in RITME is presented using visualizations, illustrations, animations, and interactive simulations to help students easily grasp the relationships between concepts.
Specifying Instructional Objectives	There is a need for learning media capable of enhancing mathematical conceptual understanding while building a Mathematical Growth Mindset through the utilization of digital technology.	RITME is developed as an AI-based learning media that supports adaptive learning, enhances conceptual understanding, and strengthens the Mathematical Growth Mindset to support Sustainable Development Goal 4 (Quality Education).

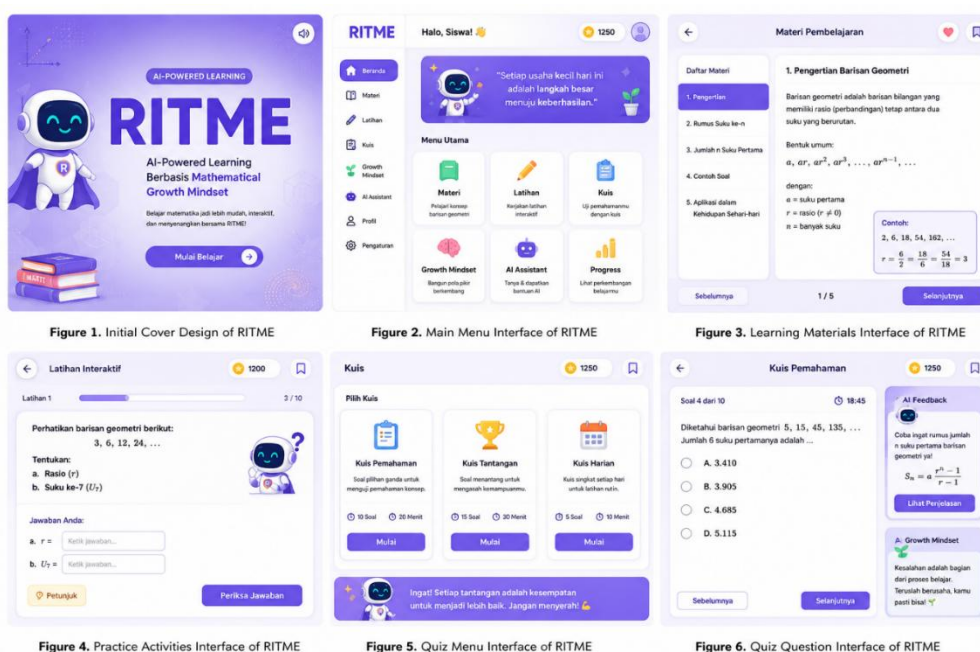
Based on the analysis in Table 3, it is evident that the development of RITME is grounded in actual needs identified during the learning process at SMP Negeri 7 Tanjungpinang. These findings indicate that the learning challenges stem not only from limited instructional media but also from student characteristics specifically, a tendency toward a fixed mindset thereby necessitating a learning approach capable of fostering both cognitive and affective aspects. The needs analysis results from the Define stage subsequently served as the foundation for the media design process in the Design stage.

Design

The Design phase aims to produce the initial prototype of the RITME learning media (AI-Powered Learning Based on Mathematical Growth Mindset) based on the needs analysis results from the Define phase. At this stage, the media structure design, learning material preparation, user interface design, research instrument compilation, and the integration of Artificial Intelligence and Mathematical Growth Mindset features into the learning media are carried out. All components are designed by paying attention to aspects of ease of use, interactivity, visual aesthetics, and a student-centered learning experience.

The RITME media is developed by presenting learning materials systematically, interactive exercises, evaluation quizzes, and Artificial Intelligence-based feedback features that provide responses tailored to the students' answers. In addition, the Mathematical Growth Mindset approach is integrated through the presentation of motivational messages, learning challenges, and reflection activities to encourage students to be more confident, persistent, and believe that mathematical abilities can develop through a continuous learning process.

The design results in the Design phase yield Prototype I of the RITME learning media, which is subsequently used as a basis in the Develop phase to undergo the validation, revision, and product quality testing processes. The user interface layout of the designed RITME learning media is presented in Figure 1.



Gambar 1. User Interface Design of RITME

Develop

The Develop phase aims to produce the RITME learning media (AI-Powered Learning Based on Mathematical Growth Mindset) that meets quality criteria before being implemented in the learning process. At this stage, Prototype I produced in the Design phase is validated by three subject matter experts and three media experts to assess aspects of content feasibility, language, presentation, graphics, interactivity, and usability. The feedback provided by the validators is used as the basis for product improvement to obtain Prototype II, which is subsequently tested on users. After the revision process is complete, the RITME media is tested on three mathematics teachers and 15 students to determine the level of practicality, followed by an effectiveness test on 15 students to determine the media's ability to support the achievement of learning objectives.

Table 4. Validity Test Results of the RITME Learning Media

Assessment Aspect	Percentage (%)	Category
Content Feasibility	92.50	Very Valid
Language	90.00	Very Valid
Presentation	94.17	Very Valid
Graphics	95.00	Very Valid
Interactivity	93.75	Very Valid
Usability	91.67	Very Valid
Average	92.85	Very Valid

Table 4 demonstrates that the RITME learning media achieved a consistently high level of validity across all assessed dimensions, with an overall average score of 92.85%, categorized as Very Valid. The highest score was obtained in the graphics aspect (95.00%), indicating that the visual design, layout, typography, and graphical presentation were considered highly appropriate and capable of supporting students' attention and comprehension. This was followed by presentation (94.17%) and interactivity (93.75%), suggesting that RITME provides well-organized learning content and interactive features that can facilitate active learner engagement. Content feasibility (92.50%) also received a very high score, confirming that the instructional materials were considered relevant, accurate, and aligned with the intended learning objectives. Meanwhile, usability (91.67%) and language (90.00%) recorded the lowest scores, although both remained within the Very Valid category, indicating that the media was generally easy to use and its language was sufficiently clear and appropriate. Overall, the narrow score range of 90.00%–95.00% indicates strong consistency among the validation dimensions and confirms that RITME possesses adequate content, linguistic, visual, interactive, and functional quality for implementation as a learning medium.

Table 5. Practicality Test Results of the RITME Learning Media

Respondent	Percentage (%)	Category
Teacher	95.20	Very Practical
Students	93.04	Very Practical
Average	94.12	Very Practical

Table 5 indicates that the RITME learning media achieved a very high level of practicality, with an overall average score of 94.12%, categorized as Very Practical. The teacher assessment reached 95.20%, representing the highest practicality score and indicating that RITME was perceived as highly feasible for classroom implementation in

terms of ease of use, clarity of instructions, accessibility of features, efficiency, and suitability for supporting instructional activities. Meanwhile, the student assessment produced a score of 93.04%, which also falls within the Very Practical category, suggesting that learners could interact with the media comfortably and use its learning materials, practice activities, and quiz features without substantial difficulty. The difference of only 2.16 percentage points between teacher and student assessments demonstrates a high degree of consistency in perceived usability across the two respondent groups. These findings suggest that RITME is not only technically and substantively valid, as demonstrated by the validity results, but is also operationally accessible to its intended users. Overall, the practicality score of 94.12% provides strong evidence that RITME can be implemented efficiently in learning settings with minimal barriers to use, while its positive reception from both teachers and students strengthens its potential as an effective and user-oriented digital learning medium.

Table 6. Effectiveness Test Results of the RITME Learning Media

Indicator	Percentage (%)	Category
Learning Media Effectiveness	89.76	Very Effective

Table 6 shows that the RITME learning media achieved an effectiveness score of 89.76%, which falls within the Very Effective category. This result indicates that RITME was highly successful in supporting the achievement of the intended learning objectives and facilitating the learning process. The high percentage suggests that the media was able to translate its validated content, interactive components, and instructional features into meaningful learning support for users. In relation to the preceding findings, the effectiveness score complements the 92.85% validity and 94.12% practicality scores, demonstrating that RITME was not only appropriate in terms of content and design and easy to implement, but also capable of producing substantial instructional benefits. Although the effectiveness score was slightly lower than the validity and practicality scores, the difference does not undermine the overall quality of the product; rather, it may reflect the distinction between perceptions of media quality and its actual contribution to learning outcomes. Therefore, the 89.76% result provides empirical support for concluding that RITME has strong potential to function as an effective digital learning medium and can be considered suitable for broader implementation in relevant learning contexts.

Discussion

The findings demonstrate that RITME achieved very high levels of validity (92.85%), practicality (94.12%), and effectiveness (89.76%). These results indicate that the product fulfilled the three essential quality dimensions of a developed educational product. This finding is consistent with the literature emphasizing systematic development and evaluation of educational technology. The use of the Four-D model also aligns with previous development studies showing that its sequential stages can support the production of feasible learning media (Hariyanto et al., 2022; Montori & Jacobus, 2025; Sihombing, 2024). However, RITME extends this development approach by integrating AI-powered learning with a mathematical growth mindset rather than focusing solely on technological or instructional media functions. The findings therefore suggest that systematic product development can accommodate both technological and psychological dimensions of mathematics learning. This integration constitutes an

important contribution of RITME to the development of student-centered digital mathematics learning.

The validity score of 92.85% indicates that RITME met the expected standards regarding content, language, presentation, graphics, interactivity, and usability. This result is consistent with studies describing AI-supported learning as increasingly capable of providing adaptive and personalized educational experiences (Demartini et al., 2024; Gligorea et al., 2023). Sajja et al. (2024) similarly highlight the potential of AI-enabled assistants to support personalized and adaptive learning. However, RITME differs from these approaches because its adaptive orientation is combined specifically with mathematical growth mindset principles. The integration is particularly relevant because mathematical mindset influences how students perceive mathematical ability and learning challenges (Im & Park, 2023; Saefudin et al., 2023). Thus, the high validity of RITME reflects not only technical and instructional feasibility but also the compatibility between AI-supported learning features and a mathematics-oriented mindset framework.

The practicality score of 94.12% indicates that RITME was highly practical for teachers and students. The result corresponds with research showing that AI-powered learning environments can facilitate engagement, accessibility, and personalized learning experiences (Chang et al., 2022; Bosch et al., 2023; Benek, 2025). Similarly, adaptive learning technologies have been associated with greater flexibility in responding to differences among learners (Akavova et al., 2023; Tan et al., 2025). Nevertheless, the present finding extends this literature by demonstrating the practical feasibility of integrating AI with mathematical growth mindset within a single mathematics learning medium. RITME provides students with structured materials, interactive activities, and feedback while maintaining a learning orientation that encourages continued effort and engagement. Therefore, its high practicality does not merely reflect ease of technical operation but also indicates that the integrated design can be implemented within ordinary mathematics learning activities without creating substantial usability barriers for teachers or students.

The effectiveness score of 89.76% indicates that RITME was highly effective in supporting students' achievement of the intended learning objectives. This finding is compatible with literature reporting positive associations between AI-supported adaptive learning and personalized educational experiences (Alam, 2022; Strielkowski et al., 2025). However, the finding should be interpreted alongside research on growth mindset, which presents a more nuanced picture. Although growth mindset has been associated with mathematics learning and achievement (Stohlmann & Yang, 2024; van Hoesve et al., 2025), Macnamara and Burgoyne (2023) caution that growth mindset interventions do not uniformly produce academic gains across contexts. Similarly, He et al. (2024) indicate that the relationship between growth mindset and mathematics achievement can vary. Thus, RITME's effectiveness should not be attributed solely to growth mindset; rather, the result may reflect the combined contribution of adaptive technology, instructional design, feedback, and mindset-oriented learning activities.

A central contribution of this study is the integration of AI-powered adaptive learning and mathematical growth mindset into one learning medium for mathematics education. Existing studies have largely examined AI in relation to personalization, adaptive learning, intelligent assistance, or student engagement (Sajja et al., 2024; Tan et al., 2025; Tang, 2026), whereas growth mindset research has primarily examined

students' beliefs, interventions, and mathematical learning behaviors (Xu et al., 2022; Stohlmann & Yang, 2024; van Hoeve et al., 2025). RITME connects these two strands by positioning AI not only as a technological mechanism for delivering learning content but also as a medium for supporting mindset-oriented learning experiences. This integration represents the principal novelty of the study. The contribution is therefore both technological and pedagogical: RITME combines adaptive digital functionality with an explicit emphasis on students' perceptions of mathematical learning, effort, persistence, and development.

The findings also have implications for SDG 4, particularly the development of quality, inclusive, and technology-supported education. The high validity, practicality, and effectiveness of RITME are consistent with studies positioning educational technology and AI as potential contributors to quality education and sustainable educational transformation (AlSagri & Sohail, 2024; Saepulmilah et al., 2025). At the same time, literature on AI in education emphasizes the need to consider equity, inclusion, ethics, and responsible implementation rather than technological advancement alone (Abuhassna et al., 2025; Flores-Viva & García-Peñalvo, 2023). In this context, RITME contributes a practical model for integrating technological and learner-centered dimensions within mathematics education. Its novelty lies not simply in using AI, but in connecting AI-supported personalization with mathematical growth mindset principles. This combination may strengthen the pedagogical orientation of digital learning toward student agency, participation, and continuous development.

Despite these contributions, the findings should be interpreted within the study's limitations. RITME was developed for geometric sequences and tested with students at one junior high school, limiting the transferability of the findings to other mathematical topics, educational levels, and learner characteristics. Moreover, the Four-D development process stopped at the Develop stage, so broader dissemination and implementation were not examined. Future research should therefore test RITME across different mathematics topics, schools, and student populations and examine its longer-term effects on mathematical achievement and mindset. Further research could also compare RITME with conventional digital media or AI-based media without growth mindset components to clarify the specific contribution of each feature. Such comparative and broader validation would extend the present findings while strengthening evidence regarding the scalability and sustainability of AI-supported, mindset-oriented mathematics learning.

CONCLUSION

This study demonstrates that RITME (AI-Powered Learning Based on Mathematical Growth Mindset) is a feasible mathematics learning medium, achieving very high validity (92.85%), practicality (94.12%), and effectiveness (89.76%). The key lesson is that integrating AI-supported learning with Mathematical Growth Mindset principles can provide not only adaptive and interactive learning experiences but also pedagogical support for students' persistence and engagement in mathematics. The implication of these findings is that AI-based learning media can be designed beyond technological functionality by incorporating learner-centered principles that address both instructional and affective dimensions of mathematics learning. Scientifically, this study contributes a development model that connects AI-powered adaptive learning with Mathematical Growth Mindset within an integrated learning medium, extending existing approaches that commonly address these dimensions separately. Nevertheless, the

study was limited to geometric sequences and implementation at SMP Negeri 7 Tanjungpinang, with dissemination beyond the development stage not conducted. Future research should examine RITME across different mathematics topics, schools, educational levels, and learner characteristics, while further developing more adaptive and personalized AI features to strengthen its scalability and contribution to sustainable digital mathematics education.

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CONFLICT OF INTEREST

There are no direct or indirect conflicts of interest related to the research, preparation, or publication of this article.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

AI (Gemini) was used to a limited extent as a supporting tool in the preparation of this manuscript. The authors independently reviewed, edited, and verified all information generated with AI assistance.

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