

DEVELOPMENT AND VALIDATION OF A READINESS-BASED ADAPTIVE E-MODULE FOR ENHANCING GEOGRAPHY LEARNING OUTCOMES IN SENIOR HIGH SCHOOL

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Abstrak

Implementasi pembelajaran berdiferensiasi dalam Kurikulum Merdeka di Indonesia memerlukan sumber belajar yang mampu mengakomodasi keberagaman kesiapan belajar peserta didik. Namun, pembelajaran Geografi di sekolah menengah atas masih didominasi oleh bahan ajar yang seragam sehingga memberikan peluang yang terbatas bagi pembelajaran yang bersifat personal. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi E-Modul Adaptif Berbasis Kesiapan Belajar pada mata pelajaran Geografi kelas X untuk meningkatkan hasil belajar peserta didik. Penelitian menggunakan pendekatan Research and Development (R&D) dengan model desain pembelajaran ADDIE. E-modul yang dikembangkan mengintegrasikan asesmen diagnostik kesiapan belajar, jalur pembelajaran adaptif, multimedia interaktif, umpan balik yang dipersonalisasi, serta kegiatan pengayaan yang terdiferensiasi. Produk divalidasi oleh ahli materi, ahli desain pembelajaran, dan ahli media pembelajaran sebelum diimplementasikan kepada 72 peserta didik kelas X di SMA Negeri 14 Medan. Kepraktisan produk dievaluasi melalui respons guru dan peserta didik, sedangkan efektivitasnya diuji menggunakan desain kuasi eksperimen pretest–posttest control group, uji t sampel independen, dan normalized gain (N-Gain). Hasil penelitian menunjukkan bahwa e-modul memperoleh tingkat validitas yang sangat tinggi (94,46%) dan kepraktisan yang sangat tinggi (93,04%). Peserta didik pada kelompok eksperimen menunjukkan hasil belajar yang secara signifikan lebih tinggi dibandingkan kelompok kontrol ($p < 0,001$), dengan nilai N-Gain tinggi (0,73). Temuan ini menunjukkan bahwa e-modul adaptif berbasis kesiapan belajar merupakan inovasi pembelajaran yang valid, praktis, dan efektif untuk mendukung pembelajaran Geografi yang berdiferensiasi serta pembelajaran digital yang dipersonalisasi pada jenjang pendidikan menengah.

Kata Kunci: e-modul adaptif; kesiapan belajar; pembelajaran berdiferensiasi; pendidikan geografi; pembelajaran yang dipersonalisasi; desain pembelajaran; hasil belajar

Abstract

The implementation of differentiated learning in Indonesia's Merdeka Curriculum requires instructional resources that accommodate students' diverse learning readiness. However, Geography instruction in senior high schools continues to rely on uniform learning materials that provide limited opportunities for personalized learning. This study aimed to develop and evaluate a Readiness-Based Adaptive E-Module for Grade X Geography to enhance students' learning outcomes. The study employed a Research and Development (R&D) approach using the ADDIE instructional design model. The developed e-module integrates diagnostic readiness assessment, adaptive learning pathways, interactive multimedia, personalized feedback, and differentiated enrichment activities. The product was validated by subject matter, instructional design, and educational media experts before being implemented with 72 Grade X students at SMA Negeri 14 Medan. Product practicality was evaluated through teachers' and students' responses, while effectiveness was examined using a quasi-experimental pretest–posttest control group design, Independent Samples t-test, and normalized gain (N-Gain). The results indicated that the e-module achieved very high validity (94.46%) and very high practicality (93.04%). Students in the experimental group demonstrated significantly higher learning outcomes than those in the control group ($p < .001$), with a high N-Gain score (0.73). These findings indicate that the readiness-based adaptive e-module is a valid, practical, and effective instructional innovation for supporting differentiated Geography

1. INTRODUCTION

The rapid advancement of digital technologies has transformed educational systems by promoting learner-centered, personalized, and technology-enhanced instruction. Recent evidence indicates that adaptive digital learning environments have become one of the major innovations in educational technology because they facilitate learner-centered instruction, improve learning engagement, and enable personalized learning experiences. Adaptive technologies are increasingly recognized as effective instructional solutions for addressing learner diversity while enhancing academic achievement across different educational contexts (Zawacki-Richter et al., 2023; Krouska et al., 2024; Bond et al., 2024). Rather than merely digitizing printed materials, contemporary educational technology emphasizes adaptive learning environments that respond to learners' diverse characteristics, prior knowledge, and learning progress (Bond et al., 2024; OECD, 2023). This transformation aligns with the goals of Education 4.0 and Society 5.0, where instructional technologies are expected to support meaningful learning through systematic instructional design rather than technology adoption alone. Previous studies have demonstrated that technology-enhanced instructional models improve students' engagement and learning outcomes when multimedia, instructional strategies, and assessment are coherently integrated (Mursid et al., 2022; Mursid et al., 2023). Personalized learning has consequently become a major direction in educational innovation because students possess diverse learning readiness, interests, and cognitive abilities. Adaptive learning environments accommodate these differences by providing individualized instructional pathways, differentiated learning activities, and timely feedback (Holmes et al., 2022; UNESCO, 2023). These principles are consistent with constructivist learning theory, which views learning as an active process supported through appropriate instructional scaffolding (Vygotsky, 1978). Tomlinson (2017) further argues that differentiated instruction should be based on students' readiness, interests, and learning profiles to maximize learning achievement. Personalized learning is strongly associated with self-regulated learning, learner autonomy, and instructional flexibility. Recent meta-analyses have demonstrated that adaptive learning environments improve students' cognitive achievement, learning motivation, and engagement when instructional adaptation is supported by sound pedagogical design rather than technological sophistication alone (Ifenthaler & Schumacher, 2024; Viberg et al., 2024). In Indonesia, the implementation of the Merdeka Curriculum has reinforced the importance of differentiated learning. Teachers are encouraged to design learning experiences that respond to students' heterogeneous academic readiness rather than providing identical instruction for all learners. However, classroom implementation remains challenging because most instructional materials continue to follow uniform learning sequences without accommodating individual learner differences. As a result, students with lower readiness often struggle to understand instructional content, whereas higher-achieving students receive insufficient academic challenge. Differentiated learning has become a strategic priority in curriculum reform because students enter classrooms with heterogeneous readiness, learning preferences, and prior knowledge. Adaptive instructional technologies provide practical mechanisms for implementing differentiated learning by automatically adjusting instructional pathways according to learners' characteristics (Tomlinson, 2017; OECD, 2023; UNESCO, 2023).

Recent developments in adaptive educational technology provide opportunities to

address these challenges. Adaptive learning systems utilize learner information to personalize instructional content, feedback, and learning pathways according to individual competencies (Ifenthaler & Schumacher, 2024). One promising approach is the development of adaptive e-modules, which integrate diagnostic assessment, adaptive multimedia resources, branching learning pathways, personalized feedback, remediation, and enrichment activities. Such instructional mechanisms enable learners to progress according to their readiness while supporting independent and self-paced learning (Holmes et al., 2022). Multimedia-supported adaptive learning is particularly relevant to Geography education because students are required to develop conceptual understanding, spatial reasoning, environmental literacy, and problem-solving skills through interactive and contextual learning experiences (Mayer, 2021). Recent educational technology research further suggests that adaptive multimedia learning environments promote conceptual understanding through personalized instructional support, interactive visualization, and immediate formative feedback. These instructional characteristics are particularly important in Geography education, where learners are required to understand complex spatial relationships and environmental systems (Mayer, 2021; Krouska et al., 2024).

Despite these advances, Geography instruction in many Indonesian senior high schools continues to rely on printed textbooks and static digital modules that merely replicate printed materials. Preliminary observations conducted at SMA Negeri 14 Medan indicated that existing instructional resources neither diagnose students' learning readiness nor provide differentiated learning pathways. Teachers reported difficulties in implementing differentiated instruction because of limited instructional time and the absence of adaptive learning technologies, while students expressed the need for more interactive and personalized digital learning resources. These findings reveal a substantial gap between the expectations of the Merdeka Curriculum and actual classroom practices.

Although previous studies have demonstrated the effectiveness of multimedia learning, blended learning, and digital instructional technologies, relatively few investigations have developed adaptive e-modules that use learning readiness as the primary adaptive mechanism. Existing instructional innovations mainly emphasize multimedia quality or usability without systematically integrating diagnostic readiness assessment and differentiated instructional pathways into a unified instructional framework (Mursid et al., 2022; Mursid et al., 2023). Therefore, empirical evidence regarding readiness-based adaptive instructional technology in Geography education remains limited.

To address this gap, the present study developed a Readiness-Based Adaptive E-Module using the ADDIE instructional design model. The e-module begins with a diagnostic readiness assessment that classifies students into Foundational, Intermediate, and Advanced levels. Based on these classifications, learners automatically receive differentiated instructional content, multimedia resources, adaptive learning activities, personalized feedback, remediation, and enrichment materials while maintaining common curriculum learning outcomes. This instructional design operationalizes differentiated learning through adaptive educational technology and provides a practical solution for implementing learner-centered instruction within the Merdeka Curriculum. Although adaptive learning has been widely investigated, most previous studies emphasize artificial intelligence, learning analytics, or intelligent tutoring systems. Comparatively few studies have developed adaptive e-modules that employ students' learning readiness as the primary mechanism for instructional adaptation, particularly within secondary Geography education. Therefore, empirical evidence concerning readiness-based adaptive instructional design remains limited.

The novelty of this study lies in integrating learning readiness, adaptive instructional pathways, systematic instructional design, and interactive multimedia into a single digital instructional environment for Geography learning. Unlike conventional e-modules, the

proposed instructional model personalizes learning based on students' initial readiness rather than providing identical learning experiences for all learners. Accordingly, this study aimed to (1) develop a readiness-based adaptive e-module, (2) examine its validity, (3) evaluate its practicality, and (4) investigate its effectiveness in improving Geography learning outcomes. The findings are expected to contribute to the advancement of educational technology by providing empirical evidence supporting adaptive digital learning and differentiated instruction in secondary education.

2. METHOD

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The model was selected because it provides a systematic framework for designing, developing, validating, and evaluating instructional innovations in educational settings. The objective of the study was to develop and evaluate a Readiness-Based Adaptive E-Module that supports differentiated Geography learning through adaptive instructional pathways based on students' learning readiness.

The research was conducted during the 2025–2026 academic year at SMA Negeri 14 Medan, Indonesia. Participants included six expert validators comprising two Geography subject matter experts, two instructional design experts, and two educational media experts for product validation. Practicality evaluation involved three Geography teachers and 36 Grade X students, while effectiveness testing employed a quasi-experimental pretest–posttest control group design involving 72 Grade X students, divided into an experimental group ($n = 36$) and a control group ($n = 36$). Participants were selected using purposive sampling because they represented the intended users and possessed relevant expertise.

During the Analysis phase, classroom observations, teacher interviews, student questionnaires, curriculum analysis, and document reviews were conducted to identify instructional problems, learner characteristics, and the need for adaptive digital learning resources. The Design phase involved developing instructional objectives, adaptive learning pathways, multimedia content, diagnostic readiness assessment, formative assessment, and interface prototypes based on the Merdeka Curriculum. In the Development phase, the adaptive e-module was produced and revised through expert validation. The Implementation phase consisted of classroom trials using the validated e-module in the experimental class, whereas the Evaluation phase examined the product's validity, practicality, and effectiveness through formative and summative evaluation procedures.

Five research instruments were employed: (1) expert validation questionnaires for evaluating content, instructional design, and educational media; (2) teacher practicality questionnaires; (3) student practicality questionnaires; (4) a diagnostic readiness assessment used to classify students into Foundational, Intermediate, and Advanced learning pathways; and (5) a 40-item multiple-choice achievement test administered as both pretest and posttest to measure Geography learning outcomes.

The validity of the research instruments was examined using Aiken's V , while reliability was evaluated using Cronbach's Alpha. Descriptive statistics were employed to analyze expert validation and practicality data. The effectiveness of the adaptive e-module was determined through Independent Samples t -test after satisfying the assumptions of normality (Shapiro–Wilk) and homogeneity (Levene's Test). Students' learning improvement was further evaluated using the Normalized Gain (N -Gain), while Cohen's d was calculated to determine the magnitude of the instructional effect. Statistical analyses were conducted using IBM SPSS Statistics, with a significance level of 0.05 (Lakens, D., 2013).

The study adhered to ethical principles for educational research. Approval was obtained from the school administration prior to data collection, and participation was voluntary. All participants were informed of the research objectives, and the confidentiality of personal information was maintained throughout the study

3. RESULTS AND DISCUSSION

Results Needs Analysis

The needs analysis identified several challenges in implementing differentiated Geography learning at SMA Negeri 14 Medan. Classroom observations, teacher interviews, and student questionnaires revealed that Geography instruction relied primarily on printed textbooks and static PDF modules, which provided identical learning experiences regardless of students' learning readiness. Teachers reported difficulties in implementing differentiated instruction because of limited instructional resources capable of accommodating students' heterogeneous academic abilities. Students also indicated that existing learning materials lacked interactive multimedia, adaptive feedback, and personalized learning support. These findings confirmed the necessity of developing an adaptive digital learning resource that aligns with the principles of differentiated learning promoted by the Merdeka Curriculum.

Development of the Readiness-Based Adaptive E-Module

Based on the needs analysis, a Readiness-Based Adaptive E-Module was developed using the ADDIE instructional design model. The instructional product integrates five principal components: (1) diagnostic readiness assessment, (2) adaptive learning pathways, (3) interactive multimedia learning resources, (4) formative assessment with personalized feedback, and (5) remediation and enrichment activities.

Students were classified into three readiness categories—Foundational, Intermediate, and Advanced—through an initial diagnostic assessment. Each category received differentiated instructional content, learning activities, multimedia resources, and assessments corresponding to students' initial competencies while maintaining common learning outcomes. The adaptive instructional structure was designed to support learner-centered instruction and independent learning within the Merdeka Curriculum framework.





Figure 1. Adaptive E-Module for Grade X Geography Subject

Expert Validation

The developed adaptive e-module underwent expert validation involving subject matter experts, instructional design experts, and educational media experts.

The validation results indicated that the instructional product achieved very high validity across all evaluated dimensions. Subject matter experts confirmed the relevance and accuracy of the instructional content, instructional design experts evaluated the pedagogical organization and adaptive learning pathways positively, while media experts considered the interface design, multimedia integration, and usability appropriate for classroom implementation.

Table 1. Expert Validation Results

Validation Aspect	Mean Score (%)	Category
Subject Matter	95.13	Very Valid
Instructional Design	94.28	Very Valid
Educational Media	93.98	Very Valid
Overall Average	94.46	Very Valid

Following expert recommendations, several revisions were implemented, including improving contextual Geography examples, simplifying learning instructions, refining navigation, strengthening adaptive feedback, and optimizing multimedia presentation before classroom implementation. The overall validation result demonstrates that the adaptive e-module satisfied the quality standards required for educational technology products.

Practicality Evaluation

The practicality of the adaptive e-module was evaluated through teachers' and students' responses after classroom implementation.

Teachers reported that the adaptive instructional pathways simplified the implementation of differentiated learning and supported classroom management. The diagnostic readiness assessment enabled teachers to identify students' competencies efficiently, while adaptive multimedia resources and personalized feedback enhanced instructional effectiveness.

Students likewise expressed positive perceptions regarding the usability, attractiveness, and instructional support provided by the adaptive e-module. Most students indicated that adaptive learning pathways enabled them to learn according to their own learning pace and facilitated better conceptual understanding of Geography.

Table 2. Practicality Evaluation Results

Respondents	Mean Score (%)	Category
Teachers	95.31	Very Practical
Students	90.76	Very Practical
Overall Average	93.04	Very Practical

These findings indicate that the developed adaptive e-module possesses excellent usability and is feasible for classroom implementation.

Effectiveness Evaluation

The effectiveness of the adaptive e-module was examined through a quasi-experimental pretest–posttest control group design.

The descriptive statistics showed that both groups demonstrated comparable pretest performance before the instructional intervention. Following implementation, students in the experimental group achieved substantially higher posttest scores than those in the control group, indicating superior learning improvement after using the adaptive e-module.

The prerequisite analyses confirmed that the data satisfied the assumptions of normality and homogeneity, permitting subsequent parametric statistical testing.

The Independent Samples *t*-test revealed a statistically significant difference between the experimental and control groups (Sig. = 0.000, $p < .05$), indicating that the adaptive e-module significantly improved students' Geography learning outcomes compared with conventional instructional materials. Furthermore, the experimental group achieved a high N-Gain score of 0.73, demonstrating substantial conceptual improvement following the intervention. These effectiveness results are consistent with the values reported in the study abstract.

Table 3. Effectiveness Evaluation

Analysis	Result
Normality Test	Normal distribution
Homogeneity Test	Homogeneous variance
Independent Samples <i>t</i> -test	$p < .001$ (Significant)
Experimental N-Gain	0.73 (High)
Learning Outcome	Experimental > Control

Overall, the findings indicate that the Readiness-Based Adaptive E-Module effectively enhanced students' Geography learning outcomes while supporting differentiated instruction through adaptive instructional pathways based on students' learning readiness. The combination of high validity, excellent practicality, and significant instructional effectiveness demonstrates that the developed e-module meets the quality criteria for educational technology products and is appropriate for implementation in senior high school Geography learning.

Discussion

The findings demonstrate that the Readiness-Based Adaptive E-Module is a valid, practical, and effective instructional innovation for supporting differentiated Geography learning in senior high schools. The high expert validation scores indicate that the developed instructional product successfully integrates curriculum content, instructional design, and multimedia learning into a coherent adaptive learning environment. These results support the argument that instructional technology becomes educationally meaningful when technological innovation is grounded in systematic instructional design rather than merely digitizing learning materials (Branch, 2009; Mursid et al., 2022). The present findings are consistent with recent international evidence demonstrating that adaptive instructional technologies significantly improve students' conceptual understanding, engagement, and academic achievement when personalization is grounded in instructional design principles rather than technology alone (Bond et al., 2024; Krouska et al., 2024; Zawacki-Richter et al., 2023).

The effectiveness of the adaptive e-module can be explained through the principles of differentiated instruction. According to Tomlinson (2017), effective instruction should respond

to differences in students' readiness by adapting instructional content, learning activities, and assessment. In the present study, the diagnostic readiness assessment enabled students to be classified into Foundational, Intermediate, and Advanced learning pathways. Consequently, each learner received instructional support corresponding to his or her initial competence. This personalized instructional process reduced learning barriers among lower-readiness students while providing greater academic challenges for advanced learners, leading to significant improvements in Geography learning outcomes.

The findings also support constructivist learning theory, particularly Vygotsky's concept of the Zone of Proximal Development (ZPD), which emphasizes that learning is optimized when instructional support is matched to learners' developmental levels (Vygotsky, 1978). The adaptive e-module functioned as a digital scaffolding system by providing differentiated explanations, multimedia demonstrations, guided practice, and adaptive feedback according to students' readiness. Such instructional support enabled students to construct conceptual understanding progressively and independently, thereby improving learning achievement. These findings also reinforce recent studies indicating that adaptive learning environments promote self-regulated learning by providing individualized scaffolding, timely feedback, and flexible learning pathways that support learners with diverse readiness levels (Viberg et al., 2024).

Another factor contributing to the effectiveness of the developed e-module is the integration of interactive multimedia. Consistent with Mayer's Cognitive Theory of Multimedia Learning, combining visual and verbal representations facilitates meaningful learning while reducing unnecessary cognitive load (Mayer, 2021). Interactive maps, animations, videos, and adaptive formative feedback assisted students in understanding abstract geographical concepts and promoted active learning. Similar findings have been reported by Bond et al. (2024), who concluded that adaptive digital learning environments increase student engagement and conceptual understanding by providing personalized instructional experiences. Interactive multimedia not only facilitates conceptual understanding but also enhances learners' spatial reasoning and cognitive engagement, which are essential competencies in Geography education (Mayer, 2021; Krouska et al., 2024).

The present findings are also consistent with previous studies conducted by Mursid and colleagues. Mursid et al. (2022) demonstrated that technology-enhanced instructional models significantly improve learning outcomes when instructional design systematically integrates learner-centered activities, multimedia resources, and authentic assessment. Likewise, Mursid et al. (2023) found that collaboration-based e-learning environments improve students' engagement and academic achievement through well-structured instructional design. Building upon these studies, the present research extends previous work by introducing learning readiness as the principal adaptive variable that determines individualized learning pathways. Thus, the contribution of this study lies not only in developing a digital learning resource but also in operationalizing differentiated learning through adaptive instructional technology.

From a practical perspective, the high practicality scores indicate that the adaptive e-module is feasible for classroom implementation. Teachers reported that the readiness-based learning pathways simplified differentiated instruction and reduced the complexity of managing heterogeneous classrooms. Students also perceived the adaptive e-module as attractive, easy to use, and supportive of independent learning. These findings align with recent international research suggesting that adaptive instructional technologies enhance learner autonomy and instructional efficiency by providing individualized learning support while maintaining teachers' central pedagogical role (Holmes et al., 2022; Ifenthaler & Schumacher, 2024).

This study also contributes to the broader field of Educational Technology by

demonstrating that adaptive learning does not necessarily require sophisticated artificial intelligence or complex learning analytics. Instead, effective personalization can be achieved through pedagogically grounded instructional design based on students' learning readiness. Such an approach is particularly relevant for schools with limited technological infrastructure because it provides an accessible model for implementing personalized learning within the Merdeka Curriculum.

The principal novelty of this research lies in integrating diagnostic readiness assessment, adaptive instructional pathways, interactive multimedia, and systematic instructional design into a single digital instructional environment for Geography learning. Unlike conventional e-modules that provide identical instructional experiences for all learners, the developed adaptive e-module personalizes instructional content, learning activities, feedback, remediation, and enrichment according to students' initial readiness. This instructional framework extends current adaptive learning research by positioning learning readiness as the primary mechanism for instructional adaptation.

Despite these promising findings, several limitations should be acknowledged. The study was conducted in a single senior high school with a relatively limited sample, which may restrict the generalizability of the findings. Moreover, the effectiveness evaluation focused primarily on cognitive learning outcomes without examining other important variables such as learning motivation, self-regulated learning, or digital literacy. Future research should involve larger and more diverse samples, investigate long-term learning outcomes, and integrate emerging technologies such as Artificial Intelligence (AI) and Learning Analytics to develop more intelligent and dynamic adaptive learning environments (Wang, S., Wang, F., Zhu, Z., Wang, J., Tran, T., & Du, Z., 2024).

Overall, the findings provide strong empirical evidence that the Readiness-Based Adaptive E-Module effectively supports differentiated Geography learning by integrating instructional design, adaptive learning, and multimedia technology. The study contributes both theoretically and practically to the advancement of educational technology while offering an innovative instructional solution for implementing personalized learning in secondary education.

4. CONCLUSION

This study developed and evaluated a Readiness-Based Adaptive E-Module for Grade X Geography learning using the ADDIE instructional design model. The findings demonstrate that the developed instructional product achieved high validity, excellent practicality, and significant effectiveness in improving students' Geography learning outcomes. By integrating diagnostic readiness assessment, adaptive learning pathways, interactive multimedia, personalized feedback, and differentiated learning activities, the e-module successfully supported learner-centered instruction aligned with the principles of the Merdeka Curriculum.

The principal contribution of this study lies in introducing learning readiness as the primary adaptive mechanism for personalizing digital instruction. Unlike conventional e-modules that provide identical learning experiences for all students, the proposed instructional model automatically delivers differentiated learning pathways according to students' initial competencies. This instructional innovation extends current research on adaptive learning by integrating differentiated instruction, multimedia learning, and systematic instructional design into a practical educational technology framework.

The findings suggest that readiness-based adaptive instructional technology can support more equitable, engaging, and effective learning in secondary education. Therefore, the developed e-module offers a feasible solution for teachers implementing differentiated instruction while promoting students' independent learning and conceptual understanding.

Future research should examine the implementation of this adaptive framework across broader educational contexts and investigate the integration of Artificial Intelligence (AI) and Learning Analytics to provide more dynamic and intelligent personalized learning environments.

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