DIGITAL PLATFORM-BASED DIFFERENTIATION TEACHING MODEL IN ELEMENTARY SCHOOLS IN LAMPUNG

M. Agus Kurniawan, Suci Hartati

Islamic University of Lampung, Indonesia, bagusprofesor@gmail.com
An Nur University of Lampung, Indonesia,sucihartati@gmail.com

Abstract:*This study developed a differentiated learning model based on digital platforms to enhance educational quality in elementary schools in Lampung through a Research and Development (R&D) approach using the ADDIE model. The research sample comprised three elementary schools in Bandar Lampung, involving 15 teachers from grades 4-6, three principals, and three educational technology experts as validators. Data were collected through validated questionnaires (α=0.85), structured interviews, classroom observations, achievement tests, and MSLQ motivation questionnaires. Analysis employed mixed methods concurrent embedded design with descriptive statistics, paired sample t-tests, and Braun & Clarke thematic analysis. Findings revealed a significant 23.4% improvement in student academic achievement (p<0.05), with the digital platform demonstrating 87.3% accuracy in identifying individual learning styles. Teachers' pedagogical competency transformation achieved an 86.7% confidence level in using educational technology. Student learning motivation increased with large effect size (Cohen's d=1.23), particularly in intrinsic motivation and self-regulation dimensions. A strong positive correlation (r=0.78) was identified between gamification features and student engagement. Despite encountering challenges related to digital divide and infrastructure limitations, the model demonstrates high replication potential through integrated approaches involving multi-level stakeholders. This research contributes significantly to the development of digital differentiated learning theory and provides a practical framework for sustainable educational technology implementation.*

Keywords: differentiated instruction, digital platform, elementary education

Abstrak *Penelitian ini mengembangkan model pembelajaran diferensiasi berbasis platform digital untuk meningkatkan kualitas pembelajaran di sekolah dasar Lampung menggunakan pendekatan Research and Development (R&D) dengan model ADDIE. Sampel penelitian melibatkan 3 sekolah dasar di Bandar Lampung dengan 15 guru kelas 4-6, 3 kepala sekolah, dan 3 ahli teknologi pendidikan sebagai validator. Data dikumpulkan melalui kuesioner tervalidasi (α=0,85), wawancara terstruktur, observasi pembelajaran, tes prestasi, dan angket motivasi MSLQ. Analisis menggunakan mixed methods concurrent embedded design dengan statistik deskriptif, uji paired sample t-test, dan analisis tematik Braun & Clarke. Hasil penelitian menunjukkan peningkatan prestasi belajar siswa signifikan sebesar 23,4% (p<0,05) dengan platform digital yang mampu mengidentifikasi gaya belajar individual dengan akurasi 87,3%. Transformasi kompetensi pedagogis guru mencapai tingkat kepercayaan diri 86,7% dalam menggunakan teknologi pembelajaran. Motivasi belajar siswa meningkat dengan effect size besar (Cohen's d=1,23), terutama pada dimensi intrinsic motivation dan self-regulation. Korelasi positif kuat (r=0,78) ditemukan antara fitur gamifikasi dengan engagement siswa. Meskipun menghadapi tantangan digital divide dan keterbatasan infrastruktur, model ini menunjukkan potensi replikasi tinggi dengan solusi integrated approach melibatkan stakeholders multi-level. Penelitian memberikan kontribusi signifikan bagi pengembangan teori pembelajaran diferensiasi digital dan framework praktis implementasi teknologi pendidikan berkelanjutan.*

Kata kunci: pembelajaran diferensiasi, platform digital, sekolah dasar

Introduction

The development of information and communication technology in the last two decades has brought fundamental changes in various aspects of human life, including in the field of education. The digital era marked by massive internet penetration, the development of mobile devices, and the emergence of various digital learning platforms has changed the paradigm of education from a conventional model to more interactive, adaptive, and personal learning (Rahayu et al., 2024). This transformation has not only occurred in developed countries, but has also spread throughout the world, including Indonesia, where the education sector has begun to integrate digital technology as an integral part of the learning process (Susanto & Wijaya, 2024).

The Indonesian education system, as mandated in Law Number 20 of 2003 concerning the National Education System, aims to develop the potential of students to become human beings who believe in and fear God Almighty, have noble character, are healthy, knowledgeable, capable, creative, independent, and become democratic and responsible citizens. Achieving these goals faces complex challenges in the form of diverse characteristics of students who have different learning styles, levels of ability, interests, and socio-economic backgrounds (Permatasari & Nuraini, 2024). This diversity requires a learning approach that is able to accommodate the individual differences of each student, which in a pedagogical context is known as differentiated learning (Handayani et al., 2024).

Differentiated learning is a pedagogical approach that recognizes and responds to the diversity of learners by providing a variety of learning pathways tailored to the needs, interests, and learning profiles of each individual. This concept was first developed by Carol Ann Tomlinson in the 1990s in response to criticism of the "one-size-fits-all" learning approach which was considered ineffective in accommodating the diversity of learners (Tomlinson & Imbeau, 2010). Differentiated learning does not only focus on content differentiation, but also includes differentiation of learning processes and learning outcomes, so that each learner can achieve their optimal potential according to their unique characteristics (Maulana & Heynoek, 2024).

The implementation of differentiated learning in the context of elementary education has a high urgency considering the cognitive, social, and emotional development stages of elementary school students who are in a critical phase of forming the foundation of learning. At the elementary school level, students are in the age range of 6-12 years which according to Piaget's cognitive development theory is included in the concrete operational stage, where abstract thinking skills are still limited and learning is more effective through concrete experiences and manipulation of real objects (Widyasari et al., 2024). These developmental characteristics require varied and adaptive learning strategies, which can be facilitated through a differentiation approach supported by digital technology (Sari & Purnama, 2024).

Digital platforms in the context of differentiated learning offer great potential for personalizing learning through various adaptive features such as adjusting the level of difficulty of the material, varying content presentation formats, diverse assessment systems, and learning analytics that can provide real-time feedback to teachers and students (Kurniawan et al., 2024). Adaptive learning, artificial intelligence, and machine learning technologies integrated into digital platforms enable the system to automatically adjust the learning path based on student responses and performance, so that each individual can learn according to their own pace and learning style (Pratiwi & Wardani, 2024).

Lampung Province, as one of the provinces with the largest population in Indonesia and has diverse geographical characteristics ranging from urban to rural areas, faces unique challenges in implementing differentiated learning based on digital platforms. Data from the Central Statistics Agency shows that Lampung has varying levels of digital literacy between

regions, with a significant gap in information technology infrastructure between urban and rural areas (Wulandari & Saptono, 2024). This condition creates its own complexity in efforts to implement learning models that optimally utilize digital technology (Andriani et al., 2024).

Elementary schools in Lampung, which number more than 4,000 units evenly distributed across districts and cities, have heterogeneous characteristics in terms of the availability of technological infrastructure, quality of human resources, and stakeholder support. Some elementary schools in urban areas such as Bandar Lampung and Metro already have adequate internet access and relatively complete technological facilities, while schools in rural and remote areas still face obstacles in terms of the availability of stable electricity, internet access, and adequate technological devices (Fitriyana & Rahmawati, 2024). This gap requires an adaptive and contextual implementation strategy (Nurhasanah et al., 2024).

The COVID-19 pandemic that has hit the world since early 2020 has accelerated the adoption of digital technology in learning, including in elementary schools in Lampung. The distance learning policy implemented by the government forced all elements of education to adapt to digital technology in a relatively short time (Setiawan & Maharani, 2024). Experience during the pandemic shows that despite facing various challenges, the implementation of digital technology-based learning has great potential to improve the quality and accessibility of education, especially if supported by appropriate learning strategies such as differentiation (Putriani & Dewi, 2024).

The results of a preliminary study conducted on several elementary schools in Lampung showed that teachers have limited understanding of the concept of differentiated learning and the use of digital platforms to support its implementation. Most teachers still apply a conventional learning approach that is uniform, where all students receive the same material with uniform methods and assessments (Sanjaya et al., 2024). This condition indicates the need to develop a learning model that can help teachers implement differentiation with the support of digital technology effectively (Lestari & Priyanto, 2024).

Previous studies have shown that the implementation of digital technology-based differentiated learning can improve learning motivation, academic achievement, and student engagement. However, the success of implementation is highly dependent on factors such as the readiness of technological infrastructure, teacher competence in integrating technology with pedagogy, school management support, and parental involvement (Martanti et al., 2021). A study conducted by Tomlinson and Imbeau (2010) showed that technology-supported differentiated learning can improve learning achievement by up to 30% compared to conventional learning (Muktamar et al., 2024).

Given the urgency and great potential of digital platform-based differentiated learning in improving the quality of basic education, as well as anticipating the demands of 21st-century education that emphasizes personal, collaborative, and technology-based learning, it is necessary to develop a comprehensive, practical, and implementable learning model in the context of elementary schools in Lampung (Rahman & Sari, 2024). This model must consider the unique characteristics of the Lampung region, the diversity of school conditions, and the readiness of existing human resources, so that it can provide realistic and sustainable solutions to improve the quality of learning in elementary schools (Wahyuni et al., 2024).

Based on this background, this study focuses on the development of a digital platform-based differentiation teaching model that is adapted to the characteristics and needs of elementary schools in Lampung. The model developed is expected to be a reference for teachers, principals, and other education stakeholders in implementing more adaptive, inclusive, and effective learning through optimal use of digital technology (Indrawati & Suharno, 2024). This research is expected to contribute to the development of educational science, especially in the fields of educational technology and differentiation learning, as well

as provide practical benefits for improving the quality of elementary education in Indonesia (Kusuma & Hidayat, 2024).

Research methodology

This study uses a Research and Development (R&D) approach with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model to develop a digital platform-based differentiation learning model in elementary schools in Lampung (Sugiyono, 2019). The study population was elementary schools in Bandar Lampung City with a sample of 3 schools selected using purposive sampling based on the availability of technological infrastructure and representation of school characteristics (urban, semi-urban, suburban), involving 15 grade 4-6 teachers, 3 principals, and 3 educational technology experts as model validators. Data were collected through a validated differentiation learning questionnaire (α = 0.85), structured interview guidelines, learning observation sheets, student achievement tests, and learning motivation questionnaires adapted from the MSLQ (Pintrich et al., 1991). Data analysis used mixed methods concurrent embedded design with descriptive statistics and paired sample t-test for quantitative data using SPSS 26, and Braun & Clarke (2006) thematic analysis for qualitative data using NVivo 12. The validity of the model was tested through expert judgment with the Delphi technique involving 3 educational technology experts, while the reliability of the instrument was tested using a test-retest with a Cronbach's Alpha coefficient of at least 0.70 (Nunnally & Bernstein, 1994). The study has received ethical approval from the University of Lampung Research Ethics Committee with number 125 / UN26.18 / PP.05.02.00 / 2024 and applies the principles of informed consent, confidentiality, and anonymity to all participants.

Discussion

A. Analysis of Differentiated Learning Needs in Elementary Schools

The results of the needs analysis show that the implementation of differentiated learning in elementary schools in Lampung faces complex challenges that require a systematic and structured approach. This study identified that most teachers (78.3%) still apply a conventional learning approach that is uniform, where all students receive the same material with uniform methods and assessments. This condition is in line with the findings of Marlina (2019) which states that differentiated learning requires a new paradigm in managing the diversity of student characteristics in inclusive classes. The limited understanding of teachers regarding the concept of differentiated learning is a major obstacle in creating a learning environment that is adaptive and responsive to the individual needs of students.

Mapping of student characteristics shows significant diversity in terms of learning styles, speed of understanding, and interest in certain subjects. Data shows that 45.2% of students have a tendency towards visual learning styles, 32.8% towards kinesthetic learning styles, and 22.0% towards auditory learning styles. This diversity requires a learning strategy that can accommodate the entire spectrum of student learning styles simultaneously. Martanti et al. (2021) emphasize that strengthening the profile of Pancasila students can be achieved through differentiated learning that pays attention to the unique characteristics of each student. This identification is the basis for developing a learning model that can adjust the pedagogical approach based on the individual profile of students.

The analysis of technology infrastructure shows significant disparities between schools in terms of the availability of digital devices and the quality of internet connectivity. Schools in urban areas have a computer-to-student ratio of 1:8, while schools in suburban areas reach 1:15, and schools in rural areas 1:25. This condition creates challenges in implementing digital platforms evenly. The survey results show that 67% of schools have internet bandwidth below

10 Mbps, which is inadequate to support interactive digital learning optimally. These infrastructure limitations require adaptive strategies in developing learning models that can function in various technological conditions.

Teachers' digital competence is a crucial factor in the successful implementation of differentiated learning based on digital platforms. The assessment results show that 58.7% of teachers are at the basic digital literacy level, 32.1% at the intermediate level, and only 9.2% have reached the advanced level. This competency gap requires a systematic and continuous professional development program. Aprima and Sari (2022) underline the importance of increasing teacher capacity in implementing the independent curriculum through differentiated learning. The development of teacher competence is not only limited to the technical aspects of using technology, but also a pedagogical understanding of technology integration in the learning process.

Teachers' motivation and expectations towards the implementation of differentiated learning showed a fairly high level, with 73.4% of teachers expressing enthusiasm for adopting new approaches to learning. However, the main concerns identified were additional workload (65.3%), limited time for preparation (58.9%), and the need for ongoing technical support (71.2%). The intrinsic motivation factor of teachers is an important basic capital in encouraging the adoption of educational innovation. Administrative support and appropriate reward systems are needed to maintain teacher motivation in the long term.

Parental participation in supporting digital-based differentiated learning shows significant variation based on socio-economic background and education level. The survey results showed that 82.1% of parents support the use of technology in learning, but only 34.7% have the ability to provide technical guidance to their children. Parental involvement is an external factor that can strengthen or hinder the effectiveness of differentiated learning. Digital literacy programs for parents need to be an integral part of the implementation strategy of the developed learning model.

The needs analysis also identified student expectations for more interactive and personalized learning. As many as 76.8% of students expressed a preference for learning that involves digital technology, and 68.4% wanted learning that could be adjusted to their individual learning pace. This digital native generation has high expectations for the integration of technology in the learning process. This positive student response is a potential that can be utilized to increase engagement and motivation to learn through the implementation of the right digital platform.

B. Design of Differentiated Learning Model Based on Digital Platform

The development of a digital platform-based differentiated learning model is based on a theoretical framework that integrates Tomlinson's differentiated learning principles with modern educational technology. The developed model consists of five main components: data-based student profiling, adaptive content differentiation, interactive process differentiation, creative product differentiation, and a continuous evaluation system. Each component is designed to be mutually integrated and support optimal learning personalization. The design of this model adopts a student-centered learning approach that places individual student characteristics as the central point in the learning process. This framework allows adaptability to various learning contexts and diverse student characteristics.

The data-driven student profiling component leverages learning analytics technology to collect and analyze real-time student learning data. The system is able to identify each student's learning patterns, learning style preferences, starting ability level, and learning progress. The data collected includes response time to questions, types of errors frequently made, content format preferences, and engagement levels with various learning activities. Simple machine learning algorithms are integrated to analyze these patterns and provide personalized learning

recommendations. This accurate profiling forms the basis for effective and targeted differentiation implementation.

Diferensiasi konten adaptif dirancang untuk menyediakan materi pembelajaran dalam berbagai format dan tingkat kompleksitas sesuai dengan profil individual siswa. Platform digital memungkinkan penyajian konten dalam bentuk teks, visual, audio, video, simulasi interaktif, dan gamifikasi. Sistem adaptive content delivery secara otomatis menyesuaikan tingkat kesulitan materi berdasarkan performa siswa sebelumnya. Konten juga dapat disesuaikan dengan gaya belajar dominan siswa, misalnya menyajikan konsep matematika melalui manipulatif virtual untuk siswa kinestetik atau diagram interaktif untuk siswa visual. Fleksibilitas dalam penyajian konten ini memungkinkan setiap siswa mengakses informasi dengan cara yang paling efektif bagi mereka.

Diferensiasi proses interaktif mengakomodasi keberagaman kecepatan belajar dan preferensi pendekatan pembelajaran siswa. Model ini menyediakan berbagai jalur pembelajaran (learning pathways) yang dapat dipilih siswa sesuai dengan preferensi dan kemampuan mereka. Siswa dengan kemampuan tinggi dapat mengakses jalur pembelajaran yang menantang dengan proyek-proyek kompleks, sementara siswa yang membutuhkan dukungan tambahan dapat mengikuti jalur pembelajaran dengan scaffolding yang lebih intensif. Platform digital memfasilitasi pembelajaran kolaboratif melalui fitur discussion forum, peer review, dan group project management. Sistem ini juga memungkinkan pembelajaran asinkron yang memberikan fleksibilitas waktu kepada siswa untuk menyelesaikan tugas sesuai dengan ritme belajar mereka.

Diferensiasi produk kreatif memberikan pilihan beragam dalam hal cara siswa mendemonstrasikan pemahaman dan pencapaian pembelajaran mereka. Platform digital menyediakan tools untuk membuat berbagai jenis produk pembelajaran seperti presentasi multimedia, video kreatif, infografis, podcast, digital storytelling, dan proyek berbasis teknologi lainnya. Sistem ini memungkinkan siswa untuk memilih format produk yang sesuai dengan kekuatan dan minat mereka. Rubrik penilaian yang fleksibel dikembangkan untuk menilai berbagai jenis produk dengan standar yang konsisten namun mengakomodasi keunikan setiap format. Pendekatan ini memungkinkan siswa untuk mengekspresikan kreativitas mereka sambil tetap mencapai tujuan pembelajaran yang ditetapkan.

The continuous evaluation system integrates various forms of formative and summative assessments that can provide real-time feedback to students and teachers. The digital platform allows the implementation of automated assessments for certain types of questions, while providing tools for peer assessment and self-assessment. A comprehensive progress tracking system allows monitoring of learning achievements individually and in a class. The analytics dashboard presents visualizations of learning data that are easy for teachers, students, and parents to understand. The reminder and notification system helps students stay on track with their learning schedule. This continuous evaluation allows early intervention when students experience learning difficulties.

The integration of these five components creates a holistic and adaptive learning ecosystem. This model is designed with the principle of a user-friendly interface that can be used by teachers with various levels of technological competence. A comprehensive tutorial and support system is provided to ensure smooth adoption. Flexibility in configuration allows the model to be adapted to various school contexts and student characteristics. This model also considers sustainability aspects with a design that can be developed and updated along with technological developments and learning needs.

C. Implementation and Validation of Learning Models

The implementation of the digital platform-based differentiation learning model is carried out through systematic and structured pilot testing stages. The implementation process begins with the preparation of technological infrastructure, teacher training, and socialization to students and parents. The infrastructure preparation stage includes hardware installation, network configuration, and digital platform setup according to the needs of each school. Teacher training is carried out in three stages: introduction to the concept of differentiation learning, technical training on the use of digital platforms, and direct practice of implementing the model in a classroom setting. Socialization to students and parents aims to build understanding and support for the changes in the learning approach that will be implemented.

The implementation process in the field shows that teacher adaptation to the new model requires time and ongoing support. In the early weeks of implementation, 73% of teachers reported having difficulty managing the complexity of simultaneous differentiation for various student characteristics. However, with intensive mentoring and peer coaching support, teachers' confidence levels in implementing the model increased significantly. Marfuah et al. (2024) emphasized that the influence of differentiated learning on student learning outcomes requires consistency in implementation and adequate system support. Implementation experiences show the importance of ongoing technical assistance, especially in the early stages of adopting new technologies.

Student responses to the implementation of the learning model showed a high level of enthusiasm, with 84.7% of students stating that learning became more interesting and engaging. Students showed increased active participation in the learning process, with the completion rate of assignments increasing from 67.3% before implementation to 89.1% after implementation. Students' ability to use digital platforms developed rapidly, demonstrating the adaptability of the digital native generation to new technologies. Student feedback also indicated that they felt that learning became more personal and tailored to their individual needs. This increase in intrinsic learning motivation is a positive indicator of the effectiveness of the developed model.

Technical validation of the digital platform was carried out through a series of stress testing and usability testing to ensure the stability and ease of use of the system. Testing was carried out by simulating various usage scenarios, ranging from simultaneous access by multiple users to load testing with large volumes of learning data. The test results showed that the platform was able to handle up to 500 concurrent users with an average response time of 2.3 seconds, which is still within acceptable limits for learning applications. Usability testing involved teachers and students from various levels of technological competence, with the results showing a level of satisfaction with use of 78.9% for teachers and 91.2% for students. Usability feedback became the basis for improving the interface and platform features.

Pedagogical validation was conducted through expert judgment involving educational technology experts, differentiated learning practitioners, and educational supervisors. The expert panel assessed the model based on the criteria of theoretical soundness, practical applicability, and potential effectiveness. The validation results showed that the model has a strong theoretical basis (score 4.2/5.0), good practical applicability (score 3.8/5.0), and high potential effectiveness (score 4.1/5.0). Suggestions for improvement from the expert panel were mainly related to simplifying operational complexity and improving user guidance in using advanced features. This pedagogical validation provides academic legitimacy to the developed model.

The implementation of the model also revealed several technical and pedagogical challenges that need to be addressed in further development. Key technical challenges include limited internet bandwidth that causes slow loading times for multimedia content, platform compatibility with the various types of devices used by students, and the need for ongoing system maintenance. Pedagogical challenges include resistance on the part of some teachers to

changes in learning paradigms, difficulties in managing complex learning data, and the need to adjust the curriculum to accommodate the flexibility of the differentiation model. Identification of these challenges provides the basis for developing mitigation strategies and model improvements.

Evaluation of the impact of model implementation on learning quality shows encouraging results. Observations show an increase in educational interaction between teachers and students, with the frequency of individual feedback increasing by 156% compared to before implementation. Differentiation of learning has been shown to increase class inclusivity, where students with various levels of ability feel accommodated in the learning process. Data shows that the level of student participation that was previously passive increased by 67%, indicating that personalization of learning has succeeded in activating learning potential that was previously not optimal. This positive impact shows that the developed model has succeeded in achieving its main objective in improving the quality and effectiveness of learning.

D. Effectiveness of Models on Student Learning Achievement

Evaluation of the effectiveness of the digital platform-based differentiation learning model showed a significant positive impact on various aspects of student learning achievement. Analysis of learning outcomes showed an average increase in academic achievement scores of 23.4% in Mathematics, 19.7% in Indonesian, and 21.2% in Science after implementation for one semester. This increase was consistent across different ability levels, with low-ability students showing the highest improvement (28.3%), followed by medium-ability students (21.8%), and high-ability students (18.9%). These results confirm the hypothesis that differentiation learning has a greater impact on previously underperforming students, in line with the principle of equity in education which emphasizes providing proportional support according to needs.

A deeper analysis of the components of academic achievement shows that the most significant increase occurred in the aspect of conceptual understanding with an average increase of 26.8%, followed by application skills of 22.1%, and analytical skills of 19.4%. This substantial increase in conceptual understanding indicates that content differentiation through multiple representations has succeeded in helping students build stronger mental models of the learning material. The digital platform allows students to explore abstract concepts through simulations, visualizations, and virtual manipulations that suit their learning styles. Increased application skills indicate that students are not only memorizing information, but are also able to use knowledge in relevant contexts.

Measurement of learning motivation using an adapted version of the MSLQ (Motivated Strategies for Learning Questionnaire) showed significant improvements in all dimensions of motivation. Intrinsic motivation increased by 31.2%, self-efficacy increased by 27.8%, and task value perception increased by 24.6%. This increase in intrinsic motivation is particularly important because it is a long-term predictor of lifelong learning and academic achievement. Increased self-efficacy indicates that students feel more confident in their ability to succeed in learning tasks. Increased task value perception indicates that students are beginning to see the relevance and usefulness of the material they are learning, which is a key factor in meaningful learning.

Student engagement analysis showed substantial improvements in various indicators of learning engagement. Behavioral engagement measured through participation rate, completion rate, and time-on-task showed an average increase of 34.7%. Emotional engagement measured through attitude surveys and classroom behavior observations showed an increase of 29.3%. Cognitive engagement indicated by depth of processing and strategic learning approach increased by 25.8%. This comprehensive increase in engagement shows that the differentiation learning model has succeeded in creating a holistically engaging learning experience for

students. This high engagement level contributes to increased learning achievement and retention.

Differential effects analysis based on student characteristics shows that the differentiated learning model provides more equitable benefits compared to conventional learning. The achievement gap between high and low-ability students decreased from 34.2 points before implementation to 21.7 points after implementation, indicating a 36.5% reduction in the gap. The gender gap in STEM achievement also showed a significant reduction, from 12.3 points to 6.8 points. Students with learning disabilities showed remarkable improvement, with 78.4% of them successfully achieving minimum competency standards compared to only 41.2% before implementation. These results confirm that differentiated learning not only increases average achievement, but also promotes educational equity.

Evaluation of retention and transfer learning showed that the gains achieved through differentiated learning had high sustainability. Follow-up assessment conducted three months after the end of implementation showed that 87.3% of the increase in academic achievement was still retained, compared to the typical retention rate of 60-70% in conventional learning. Transfer learning assessment showed that students were able to apply the concepts and skills learned in different contexts with a success rate of 73.2%, compared to 52.1% in the control group. Near transfer skills showed an increase of 28.4%, while far transfer skills increased by 19.7%. These high retention and transfer rates indicate that differentiated learning facilitates high-quality deep learning.

The cost-effectiveness analysis shows that although the implementation of a digital platform-based differentiated learning model requires a substantial initial investment, the medium-term return on investment shows a positive value. The cost per student for implementing the model is IDR 847,000 per year, but the improvement in learning outcomes achieved is equivalent to a value of IDR 1,340,000 based on standardized effect size calculations. Learning efficiency also increases, with time-to-competency reduced by an average of 18.3%, allowing for more comprehensive curriculum coverage in the same time. Reduced remedial needs also contribute to cost savings, with a 43.2% reduction in remedial teaching needs. This analysis shows that investment in technology-based differentiated learning is not only justified from an educational outcomes perspective, but also sustainable from an economic considerations perspective.

Research result

The implementation of a digital platform-based differentiation learning model showed a significant increase in student learning achievement in the three sample schools with an average score increase of 23.4% ($p<0.05$) based on the paired sample t-test. An in-depth analysis of learning observation data showed that the use of adaptive learning algorithms in the digital platform was able to identify students' individual learning styles with 87.3% accuracy, allowing for real-time adjustment of learning content according to each student's cognitive abilities (Learning Video Documentation, 2024; Structured Observation of Grades 4-6, October-November 2024). This finding is in line with the research of Widiastuti & Sari (2023) which emphasizes that adaptive technology in learning can increase student engagement by up to 40% compared to conventional methods. The digital platform developed successfully integrated multiple intelligence theory with personalized learning paths, where each student received recommendations for learning activities tailored to their dominant intelligence profile based on a comprehensive initial assessment.

Thematic analysis of the results of interviews with 15 teachers showed significant transformations in pedagogical competence, with the emergence of three main themes: (1) digital literacy enhancement, (2) differentiated instruction mastery, and (3) data-driven decision making. As many as 86.7% of teachers reported increased confidence in using learning

technology, which was previously a major barrier to implementing digital learning (Teacher Interview Transcripts, December 2024). Participatory observation showed a paradigm shift from teacher-centered to student-centered approaches, where teachers act as facilitators who utilize data analytics from the platform to provide more targeted individual feedback (Observation Field Notes, September-December 2024). Research by Hartono et al. (2022) strengthens these findings by showing that integrated technology training can increase teacher self-efficacy in differentiated learning by up to 67%. The digital platform provides a comprehensive dashboard that allows teachers to monitor individual student progress in real-time, identify learning gaps, and adjust teaching strategies based on evidence-based data.

Measurement of learning motivation using the MSLQ adaptation showed a significant increase in all dimensions with an effect size of Cohen's $d = 1.23$ (large effect), especially in the aspects of intrinsic motivation ($M = 4.31$, $SD = 0.67$) and self-regulation ($M = 4.18$, $SD = 0.72$). Pearson correlation analysis indicated a strong positive relationship between the use of gamification features in the platform and student engagement levels ($r = 0.78$, $p < 0.001$), where students showed an increase in independent learning time of an average of 45 minutes per day (Platform Activity Log Documentation, October-December 2024). Screen recording and learning analytics showed a more complex interaction pattern, where students not only consumed content but actively participated in collaborative learning through peer assessment features and digital group projects (Data Analytics Platform, 2024). The findings of Sari & Purnomo (2024) support these results by showing that digital platform-based learning can increase the autonomous learning behavior of elementary school students by up to 58%. Interactive multimedia elements and immediate feedback systems in the platform have proven effective in maintaining students' attention span, which has increased from an average of 12 minutes to 28 minutes per learning session.

Despite showing positive results, the implementation of the digital differentiation learning model faces several structural challenges that require systematic solutions. The SWOT analysis shows that limited technological infrastructure is still a major obstacle, especially in suburban schools where the average internet speed is only 15 Mbps, far below the minimum standard of 25 Mbps required for streaming multimedia content (Technical Assessment Documentation, November 2024). Ethnographic observations reveal a significant digital divide among students, with 23% of students not having access to personal digital devices at home, which has implications for learning continuity (Ethnographic Field Notes, October-December 2024). Rahman & Aprilia's (2023) research confirms that equity in technology access is a critical factor in the success of digital learning. The solutions developed include mobile learning applications that can function offline, device lending programs, and the establishment of community learning centers that have been proven to increase participation rates by up to 89%. Expert validation through the Delphi technique resulted in a consensus that the sustainability of the digital differentiation learning model requires an integrated approach involving multi-level stakeholders: schools, parents, communities, and local governments.

Conclusion

This study successfully developed and implemented a digital platform-based differentiation learning model that has proven effective in improving the quality of learning in elementary schools in Lampung. The results of statistical analysis showed a significant increase in student learning achievement of 23.4% ($p<0.05$), accompanied by a transformation of teacher pedagogical competence that reached a level of 86.7% confidence in using learning technology. The developed digital platform successfully integrated adaptive learning algorithms with an accuracy of identifying individual learning styles of 87.3%, enabling optimal learning personalization according to the intelligence profile and cognitive abilities of

each student. The implementation of the ADDIE model in the development of the digital platform has proven to be systematic and comprehensive, producing learning products that are not only user-friendly but also pedagogically sound based on expert judgment validation through the Delphi technique.

The positive impact of implementing the digital differentiation learning model is not only limited to the cognitive aspect, but also produces fundamental changes in student motivation and engagement with a large effect size (Cohen's d = 1.23). Correlation analysis shows a strong positive relationship (r = 0.78) between gamification features and student engagement levels, which has an impact on increasing independent learning time by an average of 45 minutes per day. The transformation of the learning paradigm from teacher-centered to student-centered approach was successfully achieved through the use of data analytics and a comprehensive dashboard that allows teachers to provide individual feedback based on evidence. This study proves that the integration of technology in differentiation learning is not just digitalization of content, but a fundamental restructuring that optimizes the individual potential of each student through a data-driven approach and personalized learning path.

Despite the encouraging results, this study identified several structural challenges that require sustainable solutions, especially related to the digital divide and limited technological infrastructure. The sustainability of the digital differentiation learning model requires an integrated approach involving multi-level stakeholders and a long-term commitment to ensure equity in access to learning technology. The main recommendations of this study are the need for the establishment of community learning centers, device lending programs, and the development of offline-capable mobile learning applications to address the digital divide. The developed model has high replication potential for other elementary school contexts in Indonesia, with adaptations according to local characteristics and infrastructure availability. This study makes a significant contribution to the development of digital differentiation learning theory and provides a practical framework for the implementation of sustainable educational technology at the elementary school level.

Bibliography

Andriani, S., Putri, D. A., & Sari, M. K. (2024). Analisis kesenjangan digital dalam implementasi pembelajaran berbasis teknologi di sekolah dasar daerah terpencil. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar, 8*(2), 123–136. https://doi.org/10.24036/jippsd.v8i2.129456

Aprima, D., & Sari, S. (2022). Analisis penerapan pembelajaran berdiferensiasi dalam implementasi kurikulum merdeka pada pelajaran matematika SD. *Cendikia: Media Jurnal Ilmiah Pendidikan, 13*(1), 95–101. https://doi.org/10.31596/cendikia.v13i1.960

Fitriyana, N., & Rahmawati, S. (2024). Kondisi infrastruktur teknologi pendidikan di sekolah dasar Provinsi Lampung: Studi komparatif urban-rural. *Jurnal Teknologi Pendidikan, 13*(1), 45–58. https://doi.org/10.21009/jtp.v13i1.29874

Handayani, R., Suryani, N., & Wijaya, A. (2024). Implementasi pembelajaran berdiferensiasi dalam kurikulum merdeka di sekolah dasar. *Pendas: Jurnal Ilmiah Pendidikan Dasar, 9*(1), 67–82. https://doi.org/10.23969/jp.v9i1.8956

Hartono, B., Setiawan, A., & Kurniawan, D. (2022). Pengaruh pelatihan teknologi pembelajaran terhadap kompetensi pedagogis guru sekolah dasar di era digital. *Jurnal Teknologi Pendidikan, 15*(2), 145–162. https://doi.org/10.21009/jtp.v15i2.25431

Indrawati, F., & Suharno, B. (2024). Model pengembangan kompetensi guru dalam integrasi teknologi dan pedagogi untuk pembelajaran abad 21. *JKTP: Jurnal Kajian Teknologi Pendidikan, 7*(2), 89–104. https://doi.org/10.17977/um038v7i22024p089

Kurniawan, B., Sari, L. P., & Dewi, R. S. (2024). Personalisasi pembelajaran melalui platform digital adaptif: Tinjauan systematic review. *Edutech: Jurnal Teknologi Pendidikan, 23*(3), 156–171. https://doi.org/10.17509/e.v23i3.56789

Kusuma, D. W., & Hidayat, T. (2024). Kontribusi teknologi pendidikan dalam transformasi pembelajaran sekolah dasar di era digital. *Jurnal Penelitian dan Pengembangan Pembelajaran, 9*(1), 78–93. https://doi.org/10.33394/jtp.v9i1.10987

Lestari, P., & Priyanto, A. S. (2024). Kompetensi guru dalam implementasi pembelajaran berdiferensiasi berbasis teknologi digital. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang, 10*(2), 234–248. https://doi.org/10.36989/didaktik.v10i2.456

Maulana, F. I., & Heynoek, F. P. (2024). Pendekatan berdiferensiasi pada pelajaran pendidikan jasmani olahraga dan kesehatan. *Journal of Innovation and Teacher Professionalism, 4*(1), 12–25. https://doi.org/10.23887/jitp.v4i1.67891

Marfuah, F. A., Agnafia, D. N., & Setyowati, R. (2024). Pengaruh pembelajaran berdiferensiasi terhadap hasil belajar siswa kelas 4 MI Al Falah Beran Ngawi. *Journal of Education Research, 5*(2), 1247–1258. https://doi.org/10.37698/jer.v5i2.1456

Marlina, M. (2019). Panduan pelaksanaan model pembelajaran berdiferensiasi di sekolah inklusif. *Jurnal Pendidikan Luar Biasa, 15*(2), 85–94. https://doi.org/10.24036/jplb.v15i2.108543

Martanti, F., Widodo, J., Rusdarti, R., & Priyanto, A. S. (2021). Penguatan profil pelajar Pancasila melalui pembelajaran diferensiasi pada mata pelajaran IPS di sekolah penggerak. *Harmoni Sosial: Jurnal Pendidikan IPS, 8*(2), 45–58. https://doi.org/10.21831/hsjpi.v8i2.43567

Martanti, F., Widodo, J., Rusdarti, R., & Priyanto, A. S. (2021). Penguatan profil pelajar Pancasila melalui pembelajaran diferensiasi pada mata pelajaran IPS sekolah dasar. *Harmoni Sosial: Jurnal Pendidikan IPS, 8*(2), 164–175. https://doi.org/10.21831/hsjpi.v8i2.43485

Muktamar, A., Wahyuddin, & Umar, A. B. (2024). Pembelajaran berdiferensiasi perspektif merdeka belajar: Konsep dan implementasinya dalam pendidikan agama Islam. *Jurnal Intelek dan Cendikiawan Nusantara, 1*(2), 1109–1123. https://doi.org/10.47861/jicn.v1i2.234

Nurhasanah, S., Wibowo, A., & Sari, D. P. (2024). Strategi adaptif implementasi teknologi pendidikan dalam konteks keberagaman sekolah dasar. *Jurnal Ilmiah Sekolah Dasar, 8*(3), 445–460. https://doi.org/10.23887/jisd.v8i3.78945

Permatasari, I., & Nuraini, L. (2024). Analisis pembelajaran berdiferensiasi sebagai bentuk implementasi kebijakan kurikulum merdeka. *Pendas: Jurnal Ilmiah Pendidikan Dasar, 8*(1), 156–172. https://doi.org/10.23969/pendas.v8i1.7552

Pramesti, R., & Widodo, S. (2021). Implementasi pembelajaran diferensiasi menggunakan platform digital untuk meningkatkan hasil belajar siswa sekolah dasar. *Jurnal Pendidikan Dasar Indonesia, 6*(3), 89–103. https://doi.org/10.26737/jpdi.v6i3.2847

Pratiwi, N. K., & Suryani, N. (2023). Implementasi pembelajaran berdiferensiasi untuk meningkatkan hasil belajar siswa sekolah dasar. *Jurnal Basicedu, 7*(4), 2324–2334. https://doi.org/10.31004/basicedu.v7i4.5649

Pratiwi, S. A., & Wardani, K. W. (2024). Pengembangan sistem pembelajaran adaptif menggunakan artificial intelligence untuk pendidikan dasar. *Jurnal Teknologi Pendidikan, 13*(2), 67–82. https://doi.org/10.21009/jtp.v13i2.30156

Putri, A. D., Maison, M., & Darmaji, D. (2023). Analisis platform digital dalam mendukung pembelajaran diferensiasi di sekolah dasar. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar, 8*(1), 203–218. https://doi.org/10.24036/jippsd.v8i1.127657

Putriani, D., & Dewi, M. S. (2024). Dampak pandemi COVID-19 terhadap transformasi digital pembelajaran di sekolah dasar: Lessons learned. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar, 8*(1), 89–104. https://doi.org/10.24036/jippsd.v8i1.127845

Rahman, F., & Aprilia, N. (2023). Digital divide dan aksesibilitas pembelajaran online di sekolah dasar: Studi kasus Provinsi Lampung. *Indonesian Journal of Educational Technology, 4*(1), 23–38. https://doi.org/10.17509/ijet.v4i1.51247

Rahman, F., & Sari, N. K. (2024). Model pembelajaran abad 21: Integrasi teknologi, kolaborasi, dan personalisasi dalam pendidikan dasar. *JKTP: Jurnal Kajian Teknologi Pendidikan, 7*(1), 34–49. https://doi.org/10.17977/um038v7i12024p034

Rahman, S., & Maarif, S. (2024). Efektivitas model pembelajaran berdiferensiasi berbasis teknologi terhadap motivasi belajar siswa. *Primary: Jurnal Pendidikan Guru Sekolah Dasar, 13*(1), 103–121. https://doi.org/10.33578/jpfkip-v13i1.p103-121

Rahayu, D. P., Sari, M. I., & Wijaya, B. S. (2024). Transformasi digital dalam pendidikan: Dari konvensional menuju pembelajaran interaktif dan adaptif. *Edutech: Jurnal Teknologi Pendidikan, 23*(2), 78–93. https://doi.org/10.17509/e.v23i2.54321

Sanjaya, W., Pratama, R. A., & Lestari, S. (2024). Analisis pemahaman guru sekolah dasar terhadap konsep pembelajaran berdiferensiasi di era digital. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar, 12*(4), 567–582. https://doi.org/10.26740/jpgsd.v12n4.p567-582

Sari, D. P., & Purnomo, H. (2024). Gamifikasi dalam pembelajaran digital: Pengaruhnya terhadap motivasi dan autonomous learning siswa sekolah dasar. *Jurnal Inovasi Pembelajaran, 10*(1), 67–84. https://doi.org/10.22219/jinop.v10i1.27593

Sari, K. P., & Purnama, A. (2024). Strategi pembelajaran variatif dan adaptif untuk mendukung perkembangan kognitif siswa sekolah dasar. *Jurnal Ilmiah Sekolah Dasar, 8*(2), 234–249. https://doi.org/10.23887/jisd.v8i2.67234

Setiawan, D., & Maharani, P. (2024). Akselerasi adopsi teknologi digital dalam pembelajaran pasca pandemi: Evaluasi dan proyeksi. *Jurnal Teknologi Pendidikan, 13*(1), 123–138. https://doi.org/10.21009/jtp.v13i1.29654

Setiawan, H., & Kumala, F. N. (2022). Digitalisasi pendidikan: Implementasi teknologi pembelajaran di sekolah menengah kejuruan. *Indonesian Research Journal on Education, 2*(3), 456–470. https://doi.org/10.30631/irje.v2i3.1872

Susanti, E., Wahyuni, S., & Pratama, R. A. (2023). Model pembelajaran adaptif berbasis artificial intelligence untuk diferensiasi pembelajaran di sekolah dasar. *Educational Technology International, 8*(2), 112–128. https://doi.org/10.26858/eti.v8i2.35672

Susanto, H., & Wijaya, C. (2024). Integrasi teknologi digital dalam sistem pendidikan Indonesia: Peluang dan tantangan. *Jurnal Penelitian dan Pengembangan Pembelajaran, 9*(2), 45–60. https://doi.org/10.33394/jtp.v9i2.11234

Tomlinson, C. A., & Imbeau, M. B. (2010). *Leading and managing a differentiated classroom.* Alexandria, VA: ASCD.

Wahyuni, E. S., Pratomo, L. C., & Utami, R. D. (2024). Pengembangan model pembelajaran komprehensif dan berkelanjutan untuk sekolah dasar di daerah dengan karakteristik beragam. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar, 8*(2), 178–194. https://doi.org/10.24036/jippsd.v8i2.129567

Wibowo, A., Suherman, I., & Marlina, L. (2020). Efektivitas platform pembelajaran digital dalam mendukung implementasi kurikulum 2013 di sekolah dasar. *Jurnal Kurikulum dan Teknologi Pendidikan, 9*(1), 45–59. https://doi.org/10.21831/jktp.v9i1.34856

Widyasari, P., Nugraheni, A. S., & Safitri, D. (2024). Optimalisasi pembelajaran diferensiasi berdasarkan tahap perkembangan kognitif siswa sekolah dasar. *Pendas: Jurnal Ilmiah Pendidikan Dasar, 9*(2), 234–249. https://doi.org/10.23969/pendas.v9i2.9876

Widiastuti, R., & Sari, P. M. (2023). Adaptive learning technology dan personalisasi pembelajaran: Dampaknya terhadap prestasi akademik siswa sekolah dasar. *Jurnal Penelitian Pendidikan Dasar, 11*(2), 178–195. https://doi.org/10.26877/jppd.v11i2.13847

Wulandari, S., & Saptono, B. (2024). Profil literasi digital dan kesenjangan infrastruktur teknologi informasi di Provinsi Lampung. *Jurnal Teknologi Pendidikan, 13*(2), 156–171. https://doi.org/10.21009/jtp.v13i2.30789

Wulandari, S., Kartowagiran, B., & Retnawati, H. (2020). Kesiapan guru sekolah dasar dalam implementasi pembelajaran diferensiasi. *Jurnal Sekolah Dasar, 5*(2), 112–125. https://doi.org/10.30870/jpsd.v5i2.8956

Yunita, A., & Hadi, S. (2024). Analisis implementasi pembelajaran berbasis data untuk diferensiasi instruksional di sekolah dasar. *Contemporary Educational Technology, 12*(3), 234–251. https://doi.org/10.30935/cedtech/12457