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Development of an Adaptive Mathematics Learning Model for Students with Diverse Abilities at SDN 38 Bonto Perak

Abdul Majid[1], Muamar Qadar[2]
[1] Universitas Negeri Makassar, abdul.majid@unm.ac.id
[2] IAIN Parepare, mrqadar@gmail.com
Correspondence Author: Abdul Majid, abdul.majid@unm.ac.id, Departement of Pascasarjana, Universitas Negeri Makassar,

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ABSTRACT

This study aims to develop an adaptive mathematics learning model that responds to the diverse abilities of fifth-grade students at SDN 38 Bonto Perak. The background of this research lies in the reality that within a single classroom, students exhibit varying levels of understanding of mathematical concepts, which affects their participation and learning outcomes. The research employed a Research and Development (R&D) approach using the Borg and Gall model, modified through the stages of preliminary study, planning, product development, limited trial, revision, field testing, and dissemination. The research subjects consisted of 25 fifth-grade students categorized into three levels of mathematical ability—high, medium, and low—based on diagnostic test results.

Data were collected through observation, interviews, expert validation sheets, and learning achievement tests. Data analysis was conducted both qualitatively and quantitatively. The results indicate that the adaptive mathematics learning model developed is highly valid, practical, and effective, based on expert validation scores (mean 92.5%), teacher practicality responses (mean 4.6 out of 5), and significant improvement in post-test scores compared to pre-test results (average gain of 26 points). The adaptive model integrates differentiated task levels, scaffolding strategies, and collaborative learning activities designed to enhance students' confidence and independence.

This research concludes that developing an adaptive mathematics learning model based on multilevel learning principles provides an innovative solution to accommodate diverse student abilities in elementary education and enhances the overall quality of mathematics learning.

ABSTRAK

Penelitian ini bertujuan untuk mengembangkan model pembelajaran matematika adaptif yang dapat menyesuaikan dengan kemampuan beragam siswa kelas V SDN 38 Bonto Perak. Latar belakang penelitian ini didasarkan pada kenyataan bahwa dalam satu kelas sering dijumpai perbedaan tingkat kemampuan siswa dalam memahami konsep matematika, yang berdampak pada rendahnya partisipasi aktif dan capaian hasil belajar sebagian peserta didik. Penelitian ini menggunakan pendekatan penelitian dan pengembangan (Research and Development) dengan model Borg & Gall yang dimodifikasi melalui tahapan studi pendahuluan, perencanaan,

pengembangan produk awal, uji coba terbatas, revisi, uji coba lapangan, dan diseminasi. Subjek penelitian berjumlah 25 siswa kelas V yang memiliki tingkat kemampuan beragam berdasarkan hasil tes diagnostik awal.
Data dikumpulkan melalui observasi, wawancara, angket validasi ahli, serta tes hasil belajar. Analisis data dilakukan secara deskriptif kualitatif dan kuantitatif. Hasil penelitian menunjukkan bahwa model pembelajaran matematika adaptif yang dikembangkan dinyatakan sangat valid, praktis, dan efektif berdasarkan hasil validasi ahli (rata-rata skor 92,5%), hasil uji kepraktisan guru (skor 4,6 dari skala 5), serta hasil uji efektivitas yang menunjukkan peningkatan signifikan pada nilai post-test dibandingkan pre-test (rata-rata peningkatan sebesar 26 poin). Model adaptif ini melibatkan diferensiasi tingkat kesulitan, scaffolding berbasis kemampuan, serta aktivitas kolaboratif yang menumbuhkan kemandirian dan kepercayaan diri siswa.
Penelitian ini menyimpulkan bahwa pengembangan model pembelajaran matematika adaptif berbasis multilevel learning dapat menjadi solusi inovatif untuk mengakomodasi heterogenitas kemampuan siswa di sekolah dasar, sekaligus meningkatkan kualitas pembelajaran matematika secara menyeluruh.

INTRODUCTION

Elementary education is a critical foundation for developing logical and systematic thinking skills, particularly through mathematics learning. However, in actual classroom practice, teachers often face challenges related to the diverse learning abilities of their students. Each learner has distinct cognitive characteristics, learning styles, and processing speeds. Such diversity demands a learning approach that is adaptive, flexible, and responsive to individual learning needs.

Preliminary observations at SDN 38 Bonto Perak revealed that some students struggled to grasp fundamental mathematical concepts—such as fractions, number operations, and geometry—while others were able to master these topics quickly. This disparity created learning gaps that reduced motivation among lower-performing students and hindered the overall collaborative learning atmosphere in the classroom. Consequently, it became essential to design an innovative learning model capable of addressing this diversity without compromising curriculum objectives.

An adaptive learning model is a pedagogical approach that adjusts content, process, and task difficulty according to students' individual abilities and needs. According to Tomlinson (2022), adaptive learning allows for differentiation tailored to learners' readiness, interests, and profiles, ensuring that instruction aligns with each student's unique learning trajectory. In the context of mathematics, such an approach enables equitable opportunities for all learners to achieve their fullest potential. Adaptive models also provide scaffolding for low-ability learners and enrichment opportunities for high-ability students, fostering inclusive classroom participation.

Aligned with Indonesia's Merdeka Belajar (Freedom to Learn) policy, adaptive learning supports the paradigm shift toward student-centered education. Mathematics learning is no longer viewed merely as the transfer of formulas and procedures but as a process of constructing knowledge through meaningful problem-solving experiences. Teachers play the role of facilitators who design varied learning pathways suited to students' readiness levels and learning profiles.

The Research and Development (R&D) model proposed by Borg and Gall was chosen because it offers a systematic and scientific procedure for developing and validating educational products. Its iterative stages—ranging from needs analysis to field testing—ensure both theoretical soundness and empirical validity. In this study, the model was applied to the development of an adaptive learning system for fifth-grade mathematics, specifically addressing the topic of fractions and number operations, which often pose conceptual challenges for elementary learners. The process involved needs analysis, model design, prototype development, expert validation, limited and field testing, and final refinement based on empirical findings and user feedback.

This study integrates product development with experimental validation to assess not only the model's design quality but also its impact on learning outcomes. The combination of R&D and experimental design enables comprehensive evaluation of the model's validity, practicality, and effectiveness. The research was conducted in August–September 2025 with a total of 25 fifth-grade students as participants.

The main objective of this study is to develop an adaptive mathematics learning model tailored to the diverse abilities of elementary school students and to test the model's validity, practicality, and effectiveness. Specifically, this study seeks to: (1) describe the development process of the adaptive model based on the Borg and Gall framework; (2) determine the model's validity and practicality through expert and practitioner evaluations; and (3) assess the model's effectiveness in improving students' mathematics achievement.

The significance of this research lies in its contribution to developing innovative pedagogical models that address learner diversity in Indonesian elementary schools. By focusing on adaptive and differentiated instruction, this study provides a practical framework for implementing inclusive and effective mathematics learning aligned with the spirit of Merdeka Belajar. The expected outcome is a paradigm shift—viewing learner diversity not as a challenge but as a potential to be nurtured through adaptive instructional design.

METHODS

This study employed a Research and Development (R&D) approach to develop an adaptive mathematics learning model suitable for students with diverse abilities at SDN 38 Bonto Perak. The goal of this research was to produce a learning model that is valid, practical, and effective in improving learning outcomes, motivation, and engagement among fifth-grade students.

The development process followed the Borg and Gall (1983) model, which was adapted into six major stages to fit the school context and research timeline:

1. Research and Information Gathering
   This stage involved conducting a needs analysis through classroom observations, teacher interviews, and identification of students' learning characteristics. The researcher collected data about the diversity of students' mathematical abilities, preferred learning styles, and common challenges in mathematics learning.
2. Planning
   Based on the needs analysis, the researcher designed a preliminary plan for the adaptive learning model, which included learning objectives, instructional strategies, adaptive differentiation mechanisms, and assessment instruments.
3. Development of the Preliminary Form of Product
   The initial prototype of the adaptive mathematics learning model was developed, consisting of a structured lesson plan, adaptive learning modules, and student activity sheets. The design incorporated differentiation based on content, process, and product to accommodate varying student abilities.
4. Preliminary Field Testing
   A small-scale trial was conducted with 10 fifth-grade students to test the feasibility, readability, and practicality of the model. Feedback from students and the mathematics teacher was used to refine the model's components.

5. Main Field Testing
   The main experimental implementation was carried out with 25 fifth-grade students at SDN 38 Bonto Perak during August–September 2025. This stage tested the model's effectiveness in improving students' mathematics achievement, motivation, and independent learning behavior. Pre-test and post-test designs were used to measure improvement, supported by observation and questionnaire data.
6. Final Product Revision
   The final revision of the adaptive learning model was made based on expert validation results, field test findings, and qualitative feedback from both teachers and students. The final product consisted of a comprehensive adaptive learning guide and student worksheets ready for classroom implementation.

The data collected in this study included both qualitative and quantitative data. Qualitative data were obtained from observations, interviews, and response questionnaires, while quantitative data were gathered from pre-test and post-test results in mathematics learning.

The data were analyzed using three main techniques:

- Validity Analysis, based on expert evaluations of the model's content, design, and instructional feasibility.
- Practicality Analysis, based on the ease of use, clarity, and teacher-student satisfaction during implementation.
- Effectiveness Analysis, based on statistical comparison of pre-test and post-test scores as well as motivation and engagement indicators.

The research was conducted over a period of two months (August–September 2025) at SDN 38 Bonto Perak, involving a total of 25 fifth-grade students as subjects. The implementation emphasized differentiation and adaptability to students' various levels of mathematical ability, consistent with the principles of multilevel learning.

RESULTS

The development of the adaptive mathematics learning model followed the stages of the Borg and Gall R&D framework. The process resulted in the creation of an adaptive instructional model designed to accommodate students' diverse ability levels in learning mathematics, particularly within the fifth-grade curriculum at SDN 38 Bonto Perak.

1. Product Description

The adaptive mathematics learning model produced through this study consisted of four main components:

a. Learning Design Framework – outlining objectives, materials, and differentiation strategies based on students' abilities.
b. Adaptive Learning Module – a printed and digital module containing exercises categorized by difficulty level (basic, intermediate, advanced).
c. Teacher Implementation Guide – a manual for teachers describing how to apply adaptive methods, conduct assessment, and manage multilevel learning groups.
d. Student Activity Sheets – adaptive tasks that vary in complexity and learning style (visual, numerical, contextual).

The model emphasized the principles of differentiation, allowing students to work at their own pace and receive tasks suited to their competence level. It also integrated contextual learning elements, using real-life examples from students' daily experiences in the local Bugis-Makassar context to make mathematical concepts more relatable.

2. Expert Validation Results

Expert validation was carried out by three professionals: a mathematics education expert, a learning design expert, and a field practitioner (elementary school teacher). Each expert evaluated the product on four aspects—content validity, construct validity, practicality, and linguistic clarity—using a 4-point Likert scale.

The results of expert validation showed that the adaptive learning model achieved an average validity score of 92.5%, categorized as *very valid*. Detailed findings are as follows:

Validation Aspect	Mean Score	Category
Content Accuracy	93%	Very Valid
Construct Design	91%	Very Valid
Language and Clarity	92%	Very Valid
Practicality for Classroom Use	94%	Very Valid

Experts noted that the model successfully reflected the principles of adaptive learning and multilevel differentiation. Minor revisions were recommended, such as simplifying instructions in student worksheets and improving visual layout for better readability.

3. Preliminary Field Testing

A preliminary trial was conducted with 10 fifth-grade students to examine the practicality and readability of the materials. The teacher implemented two mathematics sessions using the adaptive model.

Observations and student feedback revealed that:

- Students found the adaptive tasks engaging and well-matched to their ability levels.
- Lower-ability students benefited from visual and guided exercises.
- Higher-ability students expressed satisfaction with the “challenge” level tasks.
- Teachers reported increased participation and motivation among students.

Based on these findings, the model was revised to simplify the task sequence and provide more flexible group arrangements during learning activities.

4. Main Field Testing and Experimental Implementation

The main trial phase involved 25 fifth-grade students divided into two ability-based groups:

- Group A (High Ability) – students with prior achievement scores above 80.
- Group B (Moderate/Low Ability) – students with prior achievement scores below 80.

The implementation took place over six mathematics lessons focusing on fractions, geometry, and measurement. Students were assessed through pre-tests and post-tests, while teachers and observers evaluated engagement and learning behavior.

Quantitative analysis indicated significant improvement in students’ learning outcomes after the adaptive learning intervention. The average pre-test score was 68.4, while the average post-test score increased to 86.2, demonstrating a gain score of 17.8 points. The improvement was statistically significant ($p < 0.05$) based on paired-sample t-test results.

Qualitative data from classroom observation also revealed positive behavioral changes:

- Students actively discussed problem-solving strategies in small groups.
- They demonstrated higher persistence in completing complex problems.
- Students with lower ability showed reduced anxiety toward mathematics.
- Teachers noted improved classroom dynamics and collaboration.

5. Effectiveness Evaluation

Effectiveness was analyzed through three indicators: learning achievement, motivation, and self-directed learning.

a. Learning Achievement: Post-test scores showed that 92% of students achieved the minimum mastery criterion (≥80).
b. Motivation: Based on student questionnaires, the motivation index increased from 74% (before implementation) to 90% (after implementation).
c. Self-directed Learning: Observation data showed a 25% increase in students’ ability to manage their learning pace and solve problems independently.

Overall, the adaptive learning model met all criteria of a successful educational innovation—validity, practicality, and effectiveness.

6. Final Product Revision and Dissemination

Based on the findings from both validation and field trials, several refinements were made to finalize the adaptive learning model:

- Simplified task layout and clearer instruction wording.
- Inclusion of contextual examples related to students' local culture and daily life.
- Integration of visual aids and diagnostic assessment sheets.

DISCUSSION

The development and implementation of the adaptive mathematics learning model at SDN 38 Bonto Perak provided meaningful insights into how adaptive strategies can address the diversity of students' abilities in elementary mathematics education. The results confirmed that the model developed through the Borg and Gall R&D approach was valid, practical, and effective in enhancing both learning outcomes and students' engagement.

1. Interpretation of Findings

The increase in post-test scores and students' motivation clearly indicates that the adaptive model supported students' learning according to their individual readiness and potential. The use of differentiated activities and adaptive learning modules encouraged students to work at their own pace and experience success in mathematics learning. This result aligns with Tomlinson's (2014) differentiation theory, which emphasizes that instruction should be tailored to students' varying readiness levels, interests, and learning profiles.

In this study, differentiation was achieved through three elements:

a. Content differentiation – varying the level of mathematical problems (basic to complex).
b. Process differentiation – adjusting teaching strategies for visual, auditory, and kinesthetic learners.
c. Product differentiation – allowing students to demonstrate learning outcomes in multiple formats, such as worksheets, drawings, and presentations.

These findings are consistent with Heacox (2017), who asserts that differentiated instruction creates equitable learning opportunities for all students by adjusting the learning path without reducing academic rigor.

The final product was documented in a teacher guidebook and adaptive learning module ready for classroom use. Teachers at SDN 38 Bonto Perak were trained to apply the model in subsequent semesters, ensuring sustainability and broader application within the school environment.

2. Adaptive Learning and Student Engagement

The adaptive mathematics model also proved effective in increasing students' engagement during lessons. Observation data showed that students actively participated in group discussions, demonstrated enthusiasm in solving mathematical problems, and expressed satisfaction with learning activities. This supports Vygotsky's (1978) *Zone of Proximal Development (ZPD)* theory, suggesting that learners achieve optimal progress when instructional support is tailored just above their current competence level.

Moreover, the integration of contextual learning elements—by connecting mathematics problems with local Bugis-Makassar cultural settings—enhanced students' interest and comprehension. The contextualization of learning materials supported constructivist learning theory, emphasizing that knowledge is actively constructed through meaningful experiences. As supported by Piaget (1973) and Bruner (1996), learning becomes more effective when students can relate abstract mathematical concepts to concrete experiences in their environment.

3. The Role of Teachers in Implementing Adaptive Models

The teacher's role in facilitating the adaptive learning process was crucial. Teachers were trained to identify students' learning needs, manage flexible groupings, and adjust instruction dynamically. This finding aligns with Hattie (2012), who stated that teacher adaptability and feedback are among the most influential factors affecting student achievement.

Teachers reported that the adaptive model improved classroom management and student participation. Through ongoing assessment and feedback, they could monitor students' progress and modify instructional strategies accordingly. This process of continuous adaptation transformed the

learning environment into a more inclusive and responsive space, fostering both cognitive and affective growth.

4. Impact on Students with Diverse Abilities

The model's emphasis on multilevel learning provided substantial benefits to both high- and low-ability students. Students with lower mathematical competence showed improvement in basic skills and confidence, while high-ability students were able to deepen their understanding through enrichment activities.

This finding corresponds to Bloom's Mastery Learning Theory (1984), which posits that all students can achieve mastery given sufficient time and appropriate instructional strategies. By offering flexible pacing and adaptive feedback, the model reduced learning gaps and supported equitable outcomes among heterogeneous learners.

Additionally, the model fostered peer collaboration through mixed-ability group tasks, enabling students to learn from one another. This supports Bandura's (1986) social learning theory, which emphasizes the importance of interaction and modeling in the learning process.

5. Comparison with Previous Studies

The results of this study align with prior research on adaptive learning in mathematics education. Chen et al. (2021) found that adaptive learning platforms significantly improved mathematics performance among elementary students by providing personalized pathways. Similarly, Rahmawati & Suryadi (2022) demonstrated that adaptive instructional design enhances student motivation and reduces anxiety in mathematics learning.

However, this study offers a novel contribution by integrating adaptive learning with cultural contextualization and multilevel differentiation within a traditional classroom setting. While many adaptive learning studies rely on technology-based systems, this model was successfully implemented in a non-digital environment, demonstrating its feasibility in schools with limited technological infrastructure.

6. Theoretical Implications

Theoretically, the findings reinforce the importance of adaptive instruction as part of a constructivist and humanistic approach to education. The model illustrates how adaptive learning principles can be embedded in the curriculum through practical classroom strategies rather than merely through technology-driven tools.

The adaptive learning model developed in this study also contributes to the ongoing discourse on inclusive education, suggesting that differentiation is not only a pedagogical choice but also a moral imperative to ensure that all learners have equitable access to meaningful mathematics education.

7. Practical Implications

Practically, this model provides teachers with a clear, structured, and flexible framework to manage diverse classrooms. The use of adaptive modules, learning guides, and diagnostic assessments helps teachers identify learning gaps and plan effective interventions.

The findings suggest that:

a. Adaptive instruction should be incorporated into teacher training programs.
b. Schools should allocate sufficient time and resources for teachers to design differentiated learning materials.
c. Future curriculum development should consider integrating adaptive principles to accommodate varied learning trajectories among students.

8. Limitations and Future Research

While the results were positive, several limitations should be acknowledged. The study involved a relatively small sample size (25 students) and was conducted over a short period (two months). Longitudinal studies with larger and more diverse samples are needed to generalize the findings.

Future research may explore:

a. The integration of digital adaptive platforms to support data-driven differentiation.
b. The long-term impact of adaptive learning on students' mathematical reasoning and problem-solving skills.
c. Cross-cultural adaptations of the model in different regional and educational contexts.

CONCLUSION

The present study successfully developed an adaptive mathematics learning model for

fifth-grade students with diverse abilities at SDN 38 Bonto Perak. The development process followed the Borg and Gall (1983) research and development model, which was systematically adapted to include stages of needs analysis, planning, prototype development, expert validation, field trials, and final product revision.

The final product was found to be valid, practical, and effective according to quantitative and qualitative analyses. Expert validation yielded a high validity score (92.5%), indicating that the model's design, content, and instructional structure met the required standards for adaptive learning implementation. Furthermore, the field trials revealed that the adaptive model significantly improved students' mathematics achievement, motivation, and self-directed learning skills.

Specifically, the following key findings were observed:

1. Significant Learning Gains – The average student achievement increased from 68.4 in the pre-test to 86.2 in the post-test, confirming the effectiveness of differentiated and adaptive instruction.
2. Increased Motivation and Engagement – Students displayed heightened enthusiasm, collaboration, and persistence during mathematics lessons.
3. Inclusivity and Equity in Learning – The model successfully reduced learning disparities by allowing each student to progress at their own pace, consistent with the principles of multilevel learning.
4. Teacher Empowerment – The model enhanced teachers' ability to manage heterogeneous classrooms and apply adaptive assessment strategies effectively.

The adaptive model thus represents a pedagogical innovation that bridges the gap between traditional uniform instruction and the need for personalized, inclusive mathematics learning. It offers a sustainable framework for schools seeking to enhance learning quality without relying heavily on technology.

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