

Research Article

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Designing Interactive E-Modules Based on Differentiated Instruction and the Theory of Didactical Situations for Primary Mathematics Education

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Abstract

Background/purpose. This study aims to design and validate an interactive e-module for primary mathematics instruction grounded in differentiated instruction and the theory of didactical situations (TDS). Amid growing calls for inclusive and adaptive pedagogy under Indonesia's Merdeka Curriculum, the integration of digital technologies within differentiated instruction remains hindered by didactical, epistemological, and infrastructural challenges

Materials/methods. Employing a didactical design research approach, the study progressed through an interpretative phase—identifying ontogenic, didactical, and epistemological obstacles—and a critical phase involving expert validation and iterative refinement.

Results. Findings indicate that while technology-enhanced modules improve student engagement, barriers persist in conceptual understanding and learning autonomy. The final design incorporates adaptive pathways, inquiry-based tasks, multi-format content, and formative assessments with real-time feedback. Expert feedback emphasized the importance of increased interactivity, clearer scaffolding, and integrated teacher support.

Conclusion. The findings support the viability of combining TDS and differentiation frameworks to deliver scalable, inclusive, and pedagogically robust mathematics instruction for primary learners. This research contributes a validated instructional model responsive to diverse learning needs and scalable across various digital learning environments.

1. Introduction

High-quality mathematics education in primary schools serves as a foundational pillar for cultivating essential cognitive competencies, including problem-solving, critical thinking, memory retention, and the application of knowledge in both academic and real-world contexts. Early and conceptually rich mathematics instruction not only supports students' numerical fluency and analytical reasoning but also nurtures their capacity for logical thought and adaptive problem-solving (Schaeffer et al., 2021). Given its integral role in supporting lifelong learning and cognitive development, mathematics instruction must be intentionally structured to address the diverse learning needs, profiles, and backgrounds of students.

Differentiated instruction (DI) has emerged as a globally recognized pedagogical strategy for meeting the varied readiness levels, interests, and cognitive characteristics of learners. Within Indonesia, DI is institutionalized through the Merdeka Curriculum, which emphasizes learner-centered approaches prioritizing equity, inclusivity, and instructional adaptability (Marlina, 2020; Wahyudin et al., 2024). Rather than endorsing full individualization, DI involves systematic adjustments to the content, process, and product of instruction, ensuring meaningful access to curriculum goals for all students (Tomlinson, 2014; Tomlinson & Moon, 2013). This paradigm reflects international shifts toward inclusive education models that balance personalization with shared classroom experiences.

Despite its theoretical strengths, the practical implementation of differentiated instruction remains inconsistent—particularly in technology-enhanced learning environments. Studies indicate that Indonesian primary educators frequently encounter systemic constraints, including limited technological infrastructure, inadequate training in digital pedagogy, and insufficient integration of instructional design principles (Hapsari et al., 2018; Ramdhani et al., 2025). These challenges are compounded by the rapid evolution of national curricular mandates and the growing heterogeneity of learners, creating an urgent need for pragmatic and scalable instructional solutions.

This study addresses the critical gap in primary mathematics education by proposing the integration of differentiated instruction (DI) with the theory of didactical situations (TDS)—a learning theory emphasizing student autonomy, inquiry, and knowledge construction through well-designed problem situations (Prast et al., 2018). While TDS is conceptually aligned with the principles of DI, its application in digital contexts remains underutilized in Indonesian primary education, particularly within the framework of the Merdeka Curriculum. Empirical research that integrates DI and TDS into technology-enhanced mathematics instruction is limited; previous studies have primarily examined the challenges of implementing DI in digital environments (Hapsari et al., 2018; Ramdhani et al., 2025) without offering validated instructional models that holistically address ontogenic, didactical, and epistemological obstacles. To address this, the present research aims to design and validate an interactive e-module framework rooted in both DI and TDS, with dual objectives: enhancing teachers' instructional capacity and improving students' conceptual understanding in mathematics. The broader significance of this study lies in its potential to inform policy and practice by offering an evidence-based, adaptable model for inclusive and differentiated mathematics instruction in digitally mediated classroom settings.

The research aims to examine the following questions:

- (1) How can an interactive e-module based on DI and TDS be designed to support differentiated mathematics instruction in Indonesian primary schools?
- (2) What is the validity and practicality of the proposed e-module framework in addressing ontogenic, didactical, and epistemological obstacles, and how does it enhance student engagement, autonomy, and conceptual understanding?

2. Literature Review

2.1. Mathematics Instruction in the Merdeka Curriculum Context

The Merdeka Curriculum in Indonesia represents a transformative shift in educational strategy, particularly in the teaching of mathematics, aimed at fostering essential 21st-century competencies such as critical thinking, creativity, collaboration, and communication. This curriculum introduces a flexible and student-centered paradigm that encourages independent learning and innovation. However, its implementation faces significant challenges, including limited resources, insufficient teacher preparedness, and resistance to pedagogical change. The curriculum's long-term success depends on comprehensive implementation strategies that encompass robust teacher training, contextualized content delivery, and the development of innovative instructional materials. Research underscores the importance of flexibility and localization in curriculum design to foster responsive and dynamic learning environments (Hasan et al., 2024; Wahyuni et al., 2024).

Flexibility and student-centered learning constitute core features of the Merdeka Curriculum. By empowering schools to tailor the curriculum to meet local and contextual needs, it facilitates more meaningful and relevant learning experiences. This approach promotes active student involvement, enhancing both critical thinking and creativity (Masjudin, 2024; Yanti et al., 2024). In mathematics instruction, educators increasingly use open-ended problems as formative assessments to cultivate mathematical creativity and problem-solving skills (Mulia et al., 2024). Such strategies align with international assessment benchmarks such as TIMSS and PISA, which emphasize reasoning, problem-solving, and multiple solution paths (Anggraena, 2019). Despite these strengths, many educators encounter difficulties in understanding and implementing the principles of "freedom of learning," often struggling to integrate innovative methods into everyday classroom practices (Hasan et al., 2024; Putri et al., 2023).

To realize the curriculum's potential, more systematic professional development is required to prepare teachers for project-based and contextual learning strategies (Wahyuni et al., 2024). Teachers are envisioned not merely as content deliverers but as facilitators guiding students toward independence, resilience, and creativity (Yanti et al., 2024). This role includes cultivating students' social-emotional and moral competencies alongside cognitive development, reinforcing the curriculum's commitment to holistic education. Although implementation remains uneven, early results show promise: student outcomes demonstrate improvement in literacy and standardized assessments, with increased interest and motivation in learning, despite persistent challenges in areas such as mathematical representation (Ismaya & Yusritawati, 2023). In this context, ongoing institutional support, including government backing and resource provision, is crucial to fully realize the curriculum's vision of equitable and high-quality education.

2.2. Differentiated Instruction: Principles, Challenges, and Strategies

Differentiated instruction (DI) is a pedagogical approach designed to address the diverse needs of students by tailoring teaching methods, content, and learning environments. It is grounded in the belief that students have varied learning profiles, readiness levels, and interests, necessitating a flexible and responsive teaching strategy. Despite its potential to enhance student engagement and learning outcomes, DI presents several challenges in its implementation. DI is founded on principles of diversity and fairness, ensuring that all students have equal opportunities to succeed by accommodating their individual learning needs and preferences (Niu, 2009). It emphasizes a student-centered approach in which instruction is adapted to meet each student's unique needs, fostering an inclusive environment (Blaz, 2016). Theoretical underpinnings, such as Gardner's multiple intelligence theory and Sternberg's triarchic theory, further validate DI by recognizing the various ways students process information and demonstrate understanding (Ab Hajis & Othman, 2024).

However, the implementation of DI is often constrained by several systemic and contextual challenges. A major issue is the lack of resources, including inadequate teaching materials and infrastructure, which impede the effective adaptation of instruction (Maphumulo & Biccard, 2024; Sun & Mohd Yusof, 2024). Teachers also face significant hurdles due to insufficient professional development and training, which affects their ability to effectively apply DI strategies (Koimah et al., 2024; Rifqi, 2024). Additionally, the time-intensive nature of planning for differentiated learning and the difficulty of managing large class sizes further complicate efforts to individualize instruction (Mardhatillah & Suharyadi, 2023; Mirawati et al., 2022). There is also a risk that students may perceive differentiated tasks as unfair, which can undermine the intended inclusivity of DI (Mirawati et al., 2022; Rifqi, 2024).

To address these challenges, several strategies have been proposed. Continuous professional training is crucial to build teachers' competencies in designing and implementing DI effectively (Rifqi, 2024). Furthermore, fostering collaboration among educators and engaging with parent-teacher associations can help mobilize support and resources (Hajis & Othman, 2024; Maphumulo & Biccard, 2024). The innovative use of technology also plays a significant role by enabling the creation of varied and interactive learning materials that cater to different learning styles and needs (Rifqi, 2024). Lastly, encouraging teachers to engage in reflective practices helps them continuously refine their approaches and better align instruction with student needs (Smets & Struyven, 2018). In summary, while DI holds significant promise for inclusive education, its effective implementation requires a multifaceted strategy that addresses infrastructural, pedagogical, and perceptual challenges.

2.3. Interactive E-Modules for Differentiated Instruction

Interactive e-modules have emerged as powerful tools for differentiated learning, offering tailored educational experiences that cater to individual student needs. These digital resources leverage technology to enhance engagement, motivation, and learning outcomes by incorporating multimedia elements and interactive features. The use of e-modules aligns with differentiated instruction principles, allowing educators to customize content, process, and product design to meet diverse learning preferences and abilities. This approach not only supports varied learning styles but also fosters a more inclusive and effective educational environment. Interactive e-modules have been shown to significantly boost student motivation and engagement. For instance, in Pancasila education, e-modules developed using Flip PDF Professional were validated as effective tools for enhancing student motivation by providing visually appealing and interactive content (Dewi et al., 2024). The integration of multimedia elements such as videos and animations in e-modules makes learning more dynamic and engaging, which is crucial for maintaining student interest and participation (Manggala et al., 2024). In EFL classrooms, students using interactive e-modules demonstrated greater gains in critical thinking and engagement compared to those using traditional textbooks (Ratnawati et al., 2024). Moreover, differentiated instruction-based e-modules have been shown to enhance problem-solving abilities by aligning learning activities with students' individual needs and learning styles (Rahayu & Rosti, 2023).

Studies have consistently shown that interactive e-modules can lead to improved learning outcomes. For example, e-modules focusing on the excretory system in humans resulted in significant improvements in student performance, with a strong effect size indicating their effectiveness (Syaiful et al., 2023). Similarly, e-modules incorporating local wisdom in learning animal diversity were effective in enhancing student learning outcomes, demonstrating the potential of interactive resources to improve educational results (Winangun, 2024). E-modules offer enhanced accessibility, allowing students to learn from various locations and at flexible times, which is particularly beneficial in distance learning scenarios (Manggala et al., 2024). The ability to tailor e-modules to individual learning needs supports differentiated learning by creating an inclusive environment that accommodates diverse student profiles (Holisoh et al., 2023).

While interactive e-modules present numerous benefits, there are challenges in their development and implementation. Creating high-quality, innovative e-modules requires significant resources and expertise in both educational content and technology (Manggala et al., 2024). Additionally, ensuring that e-modules are accessible to all students, including those with limited access to technology, remains a critical consideration. Despite these challenges, the potential of e-modules to transform learning experiences and outcomes is substantial, warranting further exploration and investment in this area.

2.4. The Theory of Didactical Situations (TDS) in Mathematics Education

The theory of didactical situations (TDS) in mathematics education, developed by Guy Brousseau, is a comprehensive framework that explores the dynamics of teaching and learning mathematics. It emphasizes the role of structured situations in facilitating students' autonomous construction of knowledge. TDS is particularly focused on the interaction between students, teachers, and mathematical content, aiming to create environments where students can engage with mathematical concepts independently. This theory is structured around the concepts of didactical and a-didactical situations, which are crucial for understanding and designing effective mathematics instruction. Didactical situations involve direct teacher intervention, guiding students through content and ensuring exposure to essential knowledge (Artigue et al., 2014; Magalhães & Teixeira, 2014), while a-didactical situations promote independent student engagement with mathematical problems, encouraging deeper understanding and critical thinking (Arslan et al., 2011; Genc & Ergan, 2022). Another foundational aspect is the didactic contract, which represents the implicit expectations between teachers and students regarding roles and responsibilities in the learning process (Fuadiah, 2021; Magalhães & Teixeira, 2014).

In practice, TDS offers valuable tools for designing and analyzing mathematics instruction. It equips educators with a specialized vocabulary and set of models to understand classroom dynamics and the interplay between pedagogical elements (Bahn & Winsløw, 2019; Mangiante-Orsola et al., 2018). These tools not only enhance lesson planning but also contribute significantly to teacher professional development. Through reflective use of TDS, teachers can refine their instructional strategies, develop resources that support student learning, and adapt lessons based on observed classroom interactions (Mangiante-Orsola et al., 2018). TDS also promotes student-centered learning by structuring educational experiences around a-didactical situations, which have been linked to improved problem-solving skills and deeper application of mathematical concepts in diverse scenarios (Arslan et al., 2011; Genc & Ergan, 2022).

Although TDS is primarily applied within mathematics education, its implications extend to broader pedagogical practices. Its alignment with constructivist theories underscores the significance of learner autonomy and active engagement in knowledge construction. However, its successful implementation is contingent upon various contextual factors, including teacher preparedness and student adaptability. Adapting TDS to other disciplines and diverse educational environments necessitates thoughtful consideration and localized strategies. Nevertheless, the theory's emphasis on meaningful student interaction with content and the structured facilitation of learning positions it as a powerful framework for enhancing educational quality and inclusivity across curricula (Fuadiah, 2021; Loureiro de Lima et al., 2019).

2.5. Integrating Differentiated Instruction and the Theory of Didactical Situations

The integration of differentiated instruction (DI) and the theory of didactical situations (TDS) provides a robust pedagogical synergy for addressing diverse learner needs in mathematics education. DI offers a framework for tailoring instruction to students' readiness levels, interests, and learning profiles (Tomlinson, 2014), while TDS emphasizes structured problem situations that foster autonomous knowledge construction (Brousseau, 1997). By combining DI's adaptability with TDS's

focus on inquiry-based learning, educators can design interactive learning environments that simultaneously support personalization and conceptual rigor. This synthesis is particularly relevant in technology-enhanced contexts, where adaptive e-modules can operationalize both frameworks to facilitate student engagement, conceptual understanding, and critical thinking. Prior studies (Mangiante-Orsola et al., 2018; Prast et al., 2018) highlight the potential of such integration to enhance instructional differentiation while preserving mathematical depth and coherence.

3. Methodology

3.1. Research Design

This study employed a design didactical research (DDR) approach, grounded in the theory of didactical situations (TDS). DDR is an iterative, practice-oriented methodology aimed at designing, implementing, and evaluating didactical innovations within authentic educational settings. The research process consisted of two primary phases: the interpretative phase and the critical phase (Ramdhani et al., 2019, 2023; Suryadi, 2019).

3.1.1. Interpretative Phase

The interpretative phase focused on identifying learning obstacles faced by students and teachers in the context of differentiated mathematics instruction supported by technology. A phenomenological approach was adopted to explore participants' real-world instructional experiences.

This study employed a mixed-methods approach to investigate the challenges of implementing differentiated instruction and integrating technology in primary mathematics education. Data were collected through surveys and semi-structured interviews with teachers and students from various regions, aiming to understand the practical difficulties encountered in the classroom context. This method provided a broad perspective on the instructional landscape across diverse educational settings.

Complementing these data, classroom observations were conducted to closely examine teacher-student interactions, the use of manipulatives, and the incorporation of technology during mathematics lessons. These observations offered valuable real-time insights into how instructional practices are enacted and the role of digital tools in facilitating or hindering learning processes.

In addition, focus group discussions (FGDs) were organized with teachers and school principals to gain deeper qualitative insights into systemic and pedagogical barriers. These discussions enriched the dataset with nuanced perspectives on institutional and instructional challenges such as resource limitations and professional development needs.

For analysis, thematic coding was used to categorize the identified learning obstacles into three key dimensions. Ontogenic obstacles referred to issues stemming from students' developmental stages; didactical obstacles highlighted limitations in instructional strategies; and epistemological obstacles addressed gaps in students' conceptual understanding of mathematical ideas. These thematic dimensions were mapped onto the principles of the theory of didactical situations (TDS) to guide the formulation of targeted instructional design interventions.

3.1.2. Critical Phase

The critical phase focused on the development and refinement of a didactical design specifically intended for an interactive e-module that supports differentiated instruction in primary mathematics education. This phase was essential to ensure the instructional tool would meet diverse learning needs while aligning with established pedagogical principles.

The process began with expert FGDs involving mathematics education specialists, educational technology developers, and experienced teachers. These stakeholders collaboratively evaluated the preliminary design, provided critical feedback, and suggested concrete improvements to ensure the module's pedagogical soundness and practical applicability.

A comparative analysis was conducted to examine existing mathematics e-modules and identify both exemplary practices as well as prevailing limitations. This benchmarking exercise helped inform the refinement process by highlighting key features that enhance learner engagement and support differentiated instruction.

Building on these inputs, the design team developed a comprehensive didactical design. The final blueprint featured differentiated learning pathways tailored to varying student abilities, interactive simulations to enhance conceptual understanding, and adaptive assessments designed in accordance with the theory of didactical situations (TDS) to foster meaningful mathematical engagement.

The outputs of the critical phase included a validated framework for didactical design in interactive e-modules and a set of strategic recommendations for effectively integrating educational technology. These outcomes aim to support educators in delivering inclusive and responsive mathematics instruction for diverse primary school learners.

3.2. Research Instruments

The study employed a range of research instruments to achieve robust data triangulation and ensure the validity and reliability of findings related to differentiated instruction and technology integration. Quantitative data were collected using a questionnaire comprising three dimensions: student engagement, conceptual understanding, and learning autonomy. The questionnaire, developed via online forms, was completed by 122 primary school teachers across Indonesia through an online survey. Validity was established through expert judgment, and reliability testing yielded a Cronbach's alpha of $\alpha = 0.87$, indicating high internal consistency.

Qualitative data were gathered through semi-structured interviews and classroom observations conducted face-to-face. The interviews involved 16 primary mathematics teachers and 120 students from eight schools. These interviews explored challenges in implementing differentiated instruction, use of digital tools in mathematics teaching, perceptions of student autonomy, and suggestions for improving interactive modules. Structured observation checklists were also utilized to document classroom practices, including teacher strategies and student engagement levels during mathematics instruction. These checklists enabled consistent and objective recording of real-time instructional dynamics.

To refine and validate the interactive e-module design, FGDs were conducted with six academic experts and four practitioner experts. These sessions provided critical feedback to ensure the module's theoretical soundness and practical applicability.

Instrument validity was reinforced through rigorous expert review to ensure alignment with the study's objectives and theoretical framework, while reliability was enhanced through pilot testing and inter-rater agreement in qualitative coding. This research obtained ethical clearance from the Institutional Review Board (IRB). Informed consent was obtained from all participants, and for students, parental consent was secured to comply with ethical research standards.

4. Results

4.1. Identification of Learning Obstacles

Thematic analysis of both qualitative and quantitative data uncovered three key categories of obstacles impeding the effective implementation of differentiated, technology-supported

mathematics instruction: ontogenic, didactical, and epistemological. Each category reflects a distinct set of challenges related to student characteristics, instructional practices, and the conceptual nature of mathematics learning within digital environments.

4.1.1. Ontogenic Obstacles

Ontogenic obstacles relate to student-specific developmental and behavioral factors. Data revealed that while students showed strong interest in using technology for learning—evidenced by a high average engagement score of 4.18 on a 5-point scale—this engagement did not fully translate into deep mathematical understanding. Students demonstrated only moderate conceptual understanding, averaging 3.92, and a similarly moderate level of learning autonomy, with a mean score of 3.85. These findings suggest that motivation and interest alone are insufficient to foster independent, concept-rich learning in differentiated settings.

Table 1. Ontogenic Factors: Mean Student Scores

Dimension	Mean Score (1–5)	SD	N	Interpretation
Engagement	4.18	0.54	120	High
Conceptual Understanding	3.92	0.62	120	Moderate
Learning Autonomy	3.85	0.48	120	Moderate

4.1.2. Didactical Obstacles

Didactical challenges centered on the instructional strategies employed by teachers. Many educators reported difficulty in tailoring their teaching to meet varied student needs within a digitally mediated environment. The complexity of differentiated instruction—especially in real-time classroom settings—was compounded by limited professional capacity; many teachers lacked targeted training in using digital tools for differentiated learning. Additionally, time management emerged as a major barrier, with teachers struggling to balance flexible grouping, individualized feedback, and personalized task design within standard lesson durations.

Table 2. Key Didactical Challenges Identified by Teachers

Obstacle	Description
Instructional Strategy	Adapting methods for varied learner profiles
Professional Capacity	Inadequate training in tech-based differentiation
Time Management	Constraints on flexible and individualized instruction

4.1.3. Epistemological Obstacles

Epistemological obstacles concern students' ability to grasp and apply mathematical concepts, especially when interacting with digital tools. A prominent issue was the transfer of digital representations (e.g., graphs, animations, manipulatives) into formal symbolic reasoning, which students found moderately difficult (mean difficulty score: 3.95). Furthermore, technological infrastructure limitations—including device shortages, unstable internet connections, and inadequate access to digital learning resources—were frequently cited by teachers and students as significant impediments to instructional effectiveness.

Table 3. Epistemological and Infrastructure-Related Challenges

Challenge	Mean Score / Description
Representation Transfer Difficulty	3.95 (Moderate difficulty)
Infrastructure Limitations	Device access, connectivity, and resources

These findings underscore the importance of addressing both instructional and systemic barriers in designing effective, equitable technology-supported learning environments. Interventions should not only aim to boost student autonomy and conceptual understanding but also invest in teacher capacity-building and infrastructure enhancement.

4.2. Development of the Didactical Design

Based on insights from the interpretative phase, a structured didactical design model was developed to support differentiated mathematics instruction through an interactive e-module. The design was guided by the theory of didactical situations (TDS) and closely aligned with the differentiated instruction framework, aiming to support diverse learners through adaptive and meaningful instructional strategies.

This design model consisted of three core components from TDS—situation of devolution, mathematical situation, and situation of institutionalization—each integrating strategies for content, process, and product differentiation, along with interactive and reflective features.

Table 4. Core Components and Their Instructional Strategies

TDS Component	Instructional Strategies
Situation of Devolution	Trigger questions, virtual experiments, reflection tasks, and content differentiation (videos, texts, interactive simulations).
Mathematical Situation	Case studies, mini projects, open tasks, and process differentiation (simple vs. complex problems, heterogeneous grouping).
Situation of Institutionalization	Formal concept discussions, structured exercises, group discussions, and product differentiation (written reports, presentations, creative products), accompanied by formative and summative assessments.

4.2.1. Situation of Devolution

This phase empowers students by granting them autonomy to engage in learning experiences that align with their individual learning profiles, including their readiness levels, interests, and learning modalities. The design encourages students to initiate their learning through trigger questions crafted to provoke curiosity, elicit prior knowledge, and stimulate critical thinking. These questions act as entry points into mathematical exploration, setting the stage for deeper investigation.

To enhance engagement, virtual experiments are incorporated, enabling students to manipulate variables, observe mathematical patterns, and build conceptual understanding through hands-on digital experiences. These interactive explorations support the development of mathematical reasoning and model real-world scenarios, particularly useful for abstract concepts.

Following these exploratory experiences, students are encouraged to engage in individual reflection. Reflection tasks prompt learners to articulate their thought processes, evaluate their problem-solving strategies, and internalize key concepts. This metacognitive element plays a crucial role in deepening understanding and supporting long-term retention.

In addition to strategic design, the e-module addresses diverse learner needs through multi-format content delivery. Learning materials are offered in various forms, such as videos or images for visual learners, text or audio for linguistic and auditory learners, and interactive simulations for kinesthetic and experiential learners. These content formats are intentionally varied to maximize accessibility and engagement, ensuring that all students—regardless of their learning style—can meaningfully interact with the content.

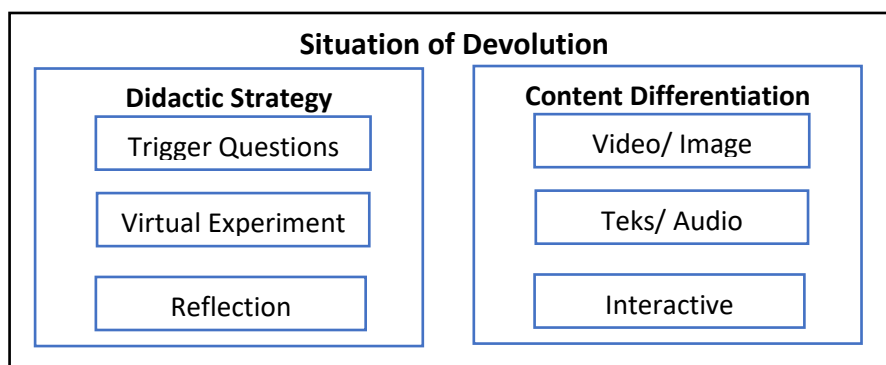


Figure 1. Devolution Phase Elements and Multimodal Content Differentiation in the Interactive e-Module

For instance, in the devolution phase, learners are given autonomy to select learning activities that match their preferences. Visual learners engage in drag-and-drop number tasks and digital coloring; auditory learners participate in singing number songs and listening to math stories; while kinesthetic learners interact with virtual manipulatives, such as dragging objects to count or playing "number jump" games.

Table 5. Integration of TDS Phases with Differentiated Strategies in the Interactive e-Module

TDS Phase	Implementation in E-Module	Differentiation Strategy
Devolution	Learners choose activities based on learning styles (e.g., songs, virtual manipulatives, digital tasks)	Choice-based learning, readiness-level selection

4.2.2. Mathematical Situation

Students are encouraged to engage in inquiry-based learning through authentic tasks such as case studies, mini projects, and open tasks. These serve as powerful vehicles for contextualized learning, allowing students to connect abstract mathematical ideas to tangible, real-life scenarios. By working through case studies, students analyze data, identify patterns, and propose solutions grounded in mathematical reasoning. Mini projects allow deeper exploration of topics, often integrating cross-disciplinary knowledge and fostering creativity.

Open tasks, which allow for multiple pathways and solutions, challenge students to explore different strategies, make decisions, and justify their reasoning—essential components of

mathematical thinking. These activities not only strengthen content mastery but also promote key 21st-century skills such as collaboration, communication, and problem-solving.

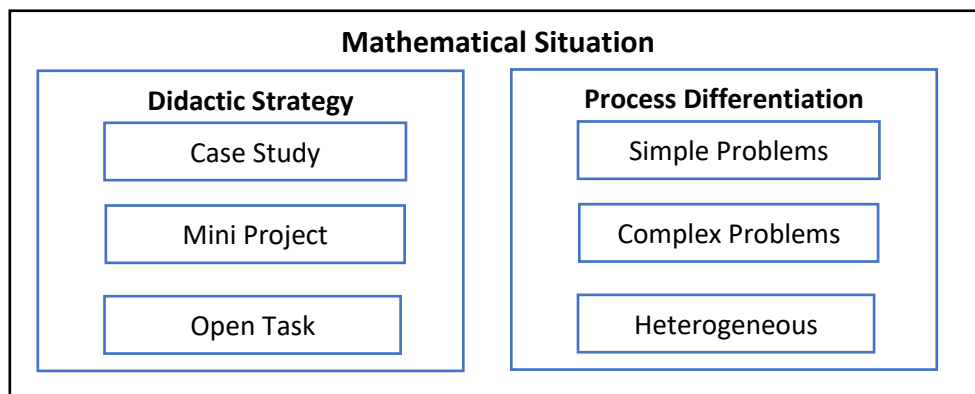


Figure 2. Inquiry-Based Task Types and Process Differentiation Strategies in the Mathematical Situation Phase

To further differentiate the learning process, these tasks are designed to vary in complexity and structure. Students may engage with simple problems that emphasize foundational skills or tackle complex problems requiring multi-step reasoning and the integration of multiple concepts. The use of heterogeneous group settings plays a crucial role, encouraging peer interaction, idea exchange, and mutual scaffolding. This collaborative environment supports diverse learners and nurtures a classroom culture of shared responsibility and inquiry.

During the mathematical situation, learners solve real-world contextual tasks (e.g., dragging the correct number to match the number of apples or completing animated math stories) to foster reasoning and inquiry. These activities promote engagement through problem-solving and discovery aligned with TDS principles.

Table 6. Integration of TDS Phases with Differentiated Strategies in the Interactive e-Module

TDS Phase	Implementation in E-Module	Differentiation Strategy
Mathematical Situation	Engagement with real-world tasks using interactive elements (e.g., drag-and-drop, virtual counting)	Tiered tasks and inquiry challenges

4.2.3. Situation of Institutionalization

In the situation of institutionalization, the instructional focus shifts toward the synthesis and formalization of mathematical knowledge. This phase enables learners to transition from exploratory understanding to structured, codified concepts. Students are guided through conceptual discussions in which they collaboratively analyze patterns, generalize findings, and construct formal mathematical expressions or models. These discussions bridge intuitive understanding with disciplinary accuracy.

Structured practice sessions are implemented to reinforce key ideas, allowing students to apply learned concepts across varied contexts. Through repeated exposure and feedback, students refine their procedural fluency and build confidence in tackling novel problems. Additionally, group

reflection activities prompt students to critically evaluate their reasoning, share perspectives, and co-construct collective knowledge.

To support diverse expression of learning, product differentiation is implemented. Learners create a range of outputs, including written reports to demonstrate analytical reasoning, presentations to showcase verbal communication, and creative products such as models, posters, or multimedia artifacts. This variety promotes inclusivity and aligns with students' strengths and preferences.

Assessment within this phase includes both formative and summative components. Formative assessments offer immediate feedback and inform instruction by identifying gaps and guiding subsequent steps. Summative assessments evaluate students' mastery at the end of a learning cycle and contribute to overall academic progress. Together, these assessment forms ensure a comprehensive understanding of both learning process and outcomes.

The e-module also incorporates adaptive features that enhance its responsiveness to student diversity. These include personalized learning pathways that adjust task difficulty based on learner progress, interactive simulations to reinforce abstract concepts, and formative assessments with instant feedback. Additionally, differentiated scaffolding strategies—such as guided prompts, tiered tasks, and visual supports—are embedded to assist learners at varying levels of proficiency. These adaptive mechanisms ensure that all students receive appropriate support while maintaining engagement and challenge.

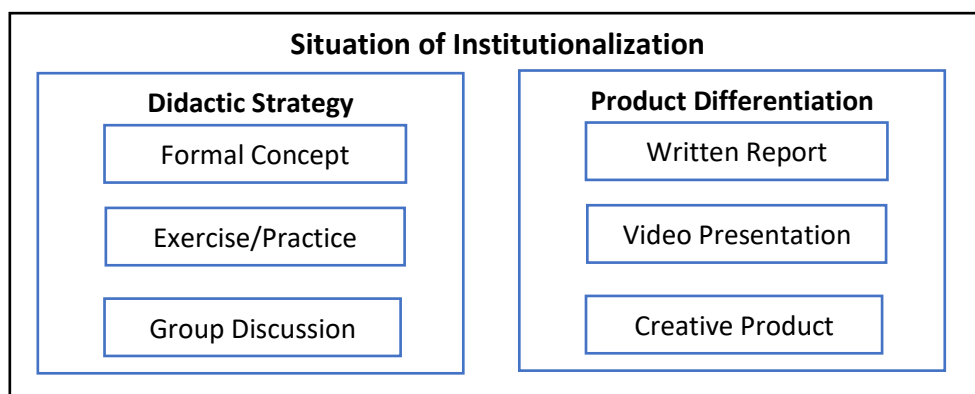


Figure 3. Institutionalization Phase Activities and Product Differentiation in the Interactive e-Module

In the Institutionalization phase, students reflect through feedback-rich assessments and produce outputs in varied forms such as digital illustrations, audio responses, or creative representations. Adaptive feedback and visual cues support the construction of formal knowledge.

Table 7. Integration of TDS Phases with Differentiated Strategies in the Interactive e-Module

TDS Phase	Implementation in E-Module	Differentiation Strategy
Institutionalization	Reflection and synthesis through multi-format assessments with adaptive feedback	Product differentiation and scaffolded outputs

The prototype design underwent a rigorous validation process through a series of FGDs. These sessions involved a diverse panel comprising mathematics education experts, educational technology developers, and practicing primary school teachers. Each stakeholder group contributed unique

perspectives, enabling the design to be critically examined from theoretical, technical, and classroom-practical viewpoints.

To clarify stakeholder contributions and design impacts, the following table summarizes key insights and resulting improvements:

Table 8. Stakeholder Feedback and e-Module Design Revisions

Stakeholder Group	Key Feedback	Revisions Implemented
Mathematics Education Experts	Emphasized student-centered assessment and deeper engagement	Increased interactivity: drag-and-drop tasks, real-time quizzes, exploratory modules
Classroom Practitioners	Highlighted the need for support for students with lower conceptual readiness	Added scaffolding strategies: visual cues, guided steps, tiered task complexity
Technology Developers & Advisors	Identified need for robust teacher support in digital learning environments.	Integrated instructional guides, classroom integration strategies, and progress monitoring dashboards

This collaborative process ensured that the final design was not only theoretically sound but also highly responsive to the realities of classroom implementation and technological feasibility.

This structured and validated didactical design ensures that the e-module is not only aligned with educational theory but also practical, inclusive, and effective for primary mathematics instruction in diverse learning environments.

5. Discussion

This study confirms the potential of interactive e-modules based on the theory of didactical situations (TDS) to address challenges in differentiated mathematics instruction at the primary level. Incorporating simulations, quizzes, and inquiry-based tasks, these modules have been shown to boost student motivation and engagement. Studies such as Suastika (2023) as well as Λαμπρόπουλος and Sidiropoulos (2024) illustrate marked improvements in student performance and enthusiasm through digital interventions. Similarly, Saenboonsong and Poonsawad (2024) and Han et al. (2024) highlight the role of gamification in fostering creativity and problem-solving. However, despite high engagement, conceptual understanding and learner autonomy remain moderate (Setambah et al., 2024), emphasizing the need for adaptive instructional design that incorporates process differentiation, such as tiered tasks and learning pathways.

The integration of the theory of didactical situations (TDS) into e-module design for primary students is a strategic approach to enhance learning experiences by structuring them around meaningful, inquiry-based activities. Developed by Guy Brousseau, TDS emphasizes the importance of creating learning environments in which students construct knowledge through interaction with well-designed tasks. This theory is particularly effective in digital learning contexts, where it can be translated into choice-based tasks, real-world problem scenarios, and scaffolded reflection activities. These components support conceptual construction (Fuadiah, 2021; Oquendo & Macancela, 2017), promote learner autonomy through dynamic tasks using tools like GeoGebra (Tamba, 2022), and accommodate individual differences in readiness and learning styles by offering varied entry points and pacing options (Almouloud, 2017; Mangiante-Orsola et al., 2018). Furthermore, TDS aligns well with inquiry-based learning by encouraging students to pose questions, investigate solutions, and reflect critically on mathematical concepts (Matematiksel et al., 2013; Rønning, 2021). Real-world

problem scenarios and scaffolded reflections bridge theory and practice, reinforcing deeper understanding (Zulkarnaen et al., 2022). TDS also benefits teachers by guiding instructional design and fostering collaboration with researchers, resulting in high-quality resources and improved practice (Mangiante-Orsola et al., 2018). While promising, implementation challenges include the need for teacher training in TDS principles and adequate technological support, emphasizing the need for deliberate design, aligned objectives, and continuous adaptation to student needs.

Persistent challenges in digital differentiation are particularly tied to teacher preparedness and instructional design. Many teachers lack the technological pedagogical content knowledge (TPACK) required to align pedagogy, content, and digital tools effectively (Adipat et al., 2023; Crompton, 2015; Padmavathi, 2017). Likewise, students often struggle to connect digital representations with formal mathematical reasoning without structured instructional scaffolds (Angelo et al., 2014; Carreira, 2015; Lapets, 2012). Effective professional development must therefore extend beyond tool usage to include holistic instructional strategies (Achieng, 2024; Groover, 2014; L. E. Martin & Mulvihill, 2022). Addressing these gaps also requires systemic investment in infrastructure and reducing teacher resistance (Bagla, 2025; Camburn & Han, 2015; Obioma, 2023).

Teacher support plays a critical mediating role. An et al. (2022) emphasize that emotional and motivational support from teachers significantly influences students' attitudes toward technology use in learning. Martin and Dowson (2009) and Sanmas et al. (2024) reinforce the importance of interpersonal relationships in enhancing motivation and digital engagement. Effective teacher training should therefore integrate communicational and emotional competencies alongside instructional tools like dashboards and digital guidance, as reflected in the e-module design of this study (Tammara & D'Alessio, 2016).

Infrastructure remains a barrier to equitable digital education. Many schools face limited access to devices, unreliable internet, and insufficient support systems, especially in rural and underserved areas (Duggi et al., 2025; Pettalongi et al., 2024; Xu, 2024). These gaps are compounded by inadequate infrastructure and policy frameworks (Biller et al., 2014). Addressing these issues calls for systemic investment and inclusive digital strategies (OECD, 2023). Teacher training and digital literacy programs, alongside community partnerships, are essential to narrowing the digital divide (Basri, 2024; Choudhary & Bansal, 2022; Memon & Memon, 2024).

Encouragingly, the post-pandemic era has seen positive behavioral adaptations among students toward digital learning. Studies report increased satisfaction and preference for hybrid models (Fabian et al., 2024; Hernández et al., 2024; Pawar & Dhawale, 2025). Students' readiness is supported by factors such as perceived usefulness and accessibility (Manasrah et al., 2024; Shaya, 2024), with user experience becoming increasingly central (Hoang & Hoang, 2022). Sustaining momentum requires ongoing institutional support and equity-driven policies (Loi et al., 2024; Macharia, 2023).

Feedback is also pivotal to conceptual learning in digital environments (Cavalcanti et al., 2020). Whiting et al. (2023) stress that timely and personalized feedback bridges digital activity and understanding. The formative assessments and real-time feedback of this study's module align with this need. Research affirms the value of goal-oriented feedback in enhancing learning outcomes (Maier & Klotz, 2022). Systems such as ScaffoldiaMyMaths (D. Sun et al., 2024) and interactive modules (Barana et al., 2021) demonstrate how personalized feedback supports mathematical communication and motivation. However, effective digital feedback requires tailored strategies in remote and hybrid contexts (Glassmeyer et al., 2022).

Despite its pedagogical strengths, differentiated instruction presents practical challenges, particularly related to planning and resources. Implementing flexible groupings, tiered assignments, and learning contracts is time-consuming and demands extensive preparation (Castle et al., 2005;

Colón et al., 2022). Moreover, resource constraints and limited training hinder scalability (Anderson & Boud, 1996). Digital solutions such as e-modules can help automate and simplify differentiation (Manggala et al., 2024), easing teacher workload while supporting personalization. However, for sustainable implementation, institutional investment in infrastructure, training, and supportive policy remains critical.

In conclusion, this research presents a validated didactical design framework integrating TDS and differentiated instruction principles through a technology-supported model. Grounded in current empirical findings, it offers a scalable and inclusive approach to enhancing mathematics instruction at the primary school level.

6. Conclusion

This study successfully developed a didactical design for interactive e-modules grounded in the principles of differentiated instruction and the theory of didactical situations (TDS) to enhance mathematics learning in primary education. The findings indicated that while technology-supported differentiated instruction increased student engagement, challenges related to conceptual understanding, learning autonomy, and infrastructure persist. The interactive e-module addressed these challenges by offering adaptive pathways, real-world mathematical contexts, immediate feedback, and differentiated scaffolding strategies. Validation through expert discussions underscored the importance of accessibility, learner-centered assessment, and embedded teacher support features. Despite existing barriers, this research presents a scalable, inclusive instructional model that can advance equitable digital transformation in primary mathematics education.

7. Suggestion

This study has several limitations that should be considered when interpreting the findings. First, the qualitative component involved only eight schools for interviews and observations, which may not fully reflect the diversity of instructional practices and technological readiness across all regions of Indonesia. As such, the transferability of insights to other contexts, particularly rural or under-resourced schools, may be constrained. Second, the reliance on self-reported data in the questionnaires, completed by 122 teachers, introduces the possibility of social desirability bias or inaccuracies in reporting their instructional practices and experiences with technology integration.

Future studies should investigate the longitudinal effects of TDS-based differentiated e-modules on student performance and autonomy across diverse educational contexts. Additionally, further exploration of teacher professional development aligned with the Technological Pedagogical Content Knowledge (TPACK) framework is recommended to support broader and more effective implementation. Expanding support systems and policies that promote infrastructure readiness and sustained teacher capacity building will also be crucial for maximizing the benefits of this instructional model.

Declarations

Author Contributions. Sendi Ramdhani: Conceptualization, Writing - Original Draft, Software, Editing and Visualization.

Novi Andri Nurcahyono: Writing - Review & Editing, Formal Analysis, and Methodology.

Sri Dewi Nirmala: Validation, Resources, Investigation and Supervision.

All authors have read and approved the published on the final version of the article prior to publication.

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Data Availability Statement. All datasets were collected and stored in compliance with institutional research ethics and privacy guidelines. Participant identifiers were removed to ensure anonymity.

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References

- Ab Hajis, S., & Othman, N. (2024). Navigating Challenges and Strategies in Implementing Differentiated Instruction: A Conceptual Overview. *International Journal of Academic Research in Business and Social Sciences*, 14(8), 1182-1199. <https://doi.org/10.6007/IJARBS/v14-i8/22153>
- Achieng, M. S. B. (2024). Teacher professional development and learning outcomes in the 21st century. *IJRDO-Journal of Educational Research*, 10(3), 46-54. <https://doi.org/10.53555/er.v10i3.6190>
- Adipat, S., Chotikapanich, R., Laksana, K., Busayanon, K., Piatanom, P., Ausawasowan, A., & Elbasouni, I. (2023). Technological Pedagogical Content Knowledge for Professional Teacher Development. *Academic Journal of Interdisciplinary Studies*, 12(1), 173-182. <https://doi.org/10.36941/ajis-2023-0015>
- Almouloud, S. A. (2017). Modelo de ensino/aprendizagem baseado em situações-problema: aspectos teóricos e metodológicos. *Revemat: Revista Eletrônica de Educação Matemática*, 11(2), 109-141. <https://doi.org/10.5007/1981-1322.2016v11n2p109>
- An, F., Yu, J., & Xi, L. (2022). Relationship between perceived teacher support and learning engagement among adolescents: Mediation role of technology acceptance and learning motivation. *Frontiers in Psychology*, 13, 1-12. <https://doi.org/10.3389/fpsyg.2022.992464>
- Anderson, G., & Boud, D. (1996). Introducing Learning Contracts: A Flexible Way to Learn. *Innovations in Education and Training International*, 33(4), 221-227. <https://doi.org/10.1080/1355800960330409>
- Angelo, J. H., Higgins, K. N., & Crawford, L. (2014). Communicating mathematical ideas in a digital writing environment: the impacts on mathematical reasoning for students with and without learning disabilities. 2(4), 68-84. <http://www.socialwelfare.eu/index.php/sw/article/view/215/0>
- Anggraena, Y. (2019). Pengembangan Kurikulum Matematika Untuk Meningkatkan Kemampuan Siswa Dalam Penalaran dan Pemecahan Masalah. *Alifmatika: Jurnal Pendidikan Dan Pembelajaran Matematika*, 1(1), 15-27. <https://doi.org/10.35316/alifmatika.2019.v1i1.15-27>
- Arslan, S., Baran, D., & Okumus, S. (2011). Brousseau's Theory of Didactical Situations in Mathematics and An Application of Adidactical Situations. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, 5(1), 204-224.

- Artigue, M., Haspekian, M., & Corblin-Lenfant, A. (2014). *Introduction to the Theory of Didactical Situations (TDS)* (pp. 47–65). Springer International Publishing. https://doi.org/10.1007/978-3-319-05389-9_4
- Bagla, M. (2025). Challenges and Opportunities in Rural Education: Bridging Gaps Through Innovation. *International Journal for Multidisciplinary Research*, 7(1), 1-7. <https://doi.org/10.36948/ijfmr.2025.v07i01.35200>
- Bahn, J., & Winsløw, C. (2019). *Doing and Investigating Lesson Study with the Theory of Didactical Situations* (pp. 83–101). https://doi.org/10.1007/978-3-030-04031-4_5
- Barana, A., Marchisio, M., & Sacchet, M. (2021). Interactive feedback for learning mathematics in a digital learning environment. *Education Sciences*, 11(6), 279. <https://doi.org/10.3390/EDUCSCI11060279>
- Basri, H. (2024). The Effectiveness of Blended Learning, Digital Literacy Programs, and Teacher Training on Student Outcomes in 2024. *Global International Journal of Innovative Research*, 2(8), 1745–1752. <https://doi.org/10.59613/global.v2i8.249>
- Biller, D., Andres, L. A., & Dappe, M. H. (2014). *Infrastructure gap in South Asia: inequality of access to infrastructure services*. World Bank Group. <https://doi.org/10.1596/1813-9450-7033>
- Blaz, D. (2016). *Differentiated Instruction*. Routledge. <https://doi.org/10.4324/9781315695648>
- Brousseau, G. (1997). *Theory of Didactical Situations in Mathematics*. Kluwer, Dordrecht.
- Camburn, E. M., & Han, S. W. (2015). Infrastructure for teacher reflection and instructional change: An exploratory study. *Journal of Educational Change*, 16(4), 511–533. <https://doi.org/10.1007/S10833-015-9252-6>
- Carreira, S. (2015). *Mathematical Problem Solving Beyond School: Digital Tools and Students' Mathematical Representations* (pp. 93–113). Springer, Cham. https://doi.org/10.1007/978-3-319-17187-6_6
- Castle, S., Deniz, C. B., & Tortora, M. (2005). Flexible Grouping and Student Learning in a High-Needs School. *Education and Urban Society*, 37(2), 139–150. <https://doi.org/10.1177/0013124504270787>
- Cavalcanti, A. P., Rolim, V., Mello, R. F., & de Freitas, F. L. G. (2020). Uma Análise entre Boas Práticas de Feedback em Ambientes Virtuais de Aprendizagem. In *Simpósio Brasileiro de Informática na Educação (SBIE)* (pp. 962-971). SBC. <https://doi.org/10.5753/CBIE.SBIE.2020.962>
- Choudhary, H., & Bansal, N. (2022). Addressing Digital Divide through Digital Literacy Training Programs: A Systematic Literature Review. *Digital Education Review*, 41, 224–248. <https://doi.org/10.1344/der.2022.41.224-248>
- Colón, G., Zgliczynski, T., & Maheady, L. (2022). *Using Flexible Grouping. In High Leverage Practices for Inclusive Classrooms* (pp. 265–281). Routledge. <https://doi.org/10.4324/9781003148609-23>
- Crompton, H. (2015). Preparing teachers to use technology effectively using the technological, pedagogical, content knowledge (tpack) framework. *Glokalde*, 1(2), 82-92. https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1047&context=teachinglearning_fac_pubs
- Dewi, S., Alfiantra, A., & Safitri, S. (2024). Enhancing Pancasila Education through Differentiated Learning: The Role of E-Modules Developed with Flip PDF Professional. *AL-ISHLAH: Jurnal Pendidikan*, 16(4), 4630–4640. <https://doi.org/10.35445/alishlah.v16i4.5337>

- Duggi, N., Bhadri, S., & Varala, C. R. (2025). Gaps in the Grid: Access and the Digital Inequality Crisis. *Digital Crossroads: Integrating Humanities, Science and Technology Edition 1*, 152-162. <https://doi.org/10.9734/bpi/mono/978-93-48859-10-5/ch13>
- Fabian, K., Smith, S., & Taylor-Smith, E. (2024). Being in Two Places at the Same Time: a Future for Hybrid Learning Based on Student Preferences. *TechTrends*, 68(4), 693-704. <https://doi.org/10.1007/s11528-024-00974-x>
- Fuadiah, N. F. (2021). Theory Of Didactical Situation (TDS), Kajian Karakteristik dan Penerapannya dalam Pembelajaran Matematika. *Jurnal Pendidikan Matematika (JUDIKA EDUCATION)*, 4(2), 160–169. <https://doi.org/10.31539/judika.v4i2.3054>
- Genc, M., & Ergan, S. (2022). Teaching geometry through didactical situations: the case of the triangle inequality. *Acta Didactica Napocensia*, 15(2), 123-141. <https://doi.org/10.24193/adn.15.2.8>
- Glassmeyer, D., Colclasure, M., & Alevy, L. (2022). Providing Virtual Mathematics Feedback: Connecting Research to Practice. *Georgia Educational Researcher*, 19(1), 47-61. <https://doi.org/10.20429/ger.2022.190103>
- Groover, R. C. (2014). *Effective Professional Development: Which Factors Matter in Implementation?* (Doctoral dissertation). <https://deepblue.lib.umich.edu/handle/2027.42/110310>
- Hajis, S. A., & Othman, N. (2024). Navigating Challenges and Strategies in Implementing Differentiated Instruction: A Conceptual Overview. *International Journal of Academic Research in Business and Social Sciences*, 14(8), 766-784. <https://doi.org/10.6007/ijarbss/v14-i8/22153>
- Han, M., Yang, Y., & Sun, Y. (2024). Cultivation of Creative Thinking of Middle School Students Under Gamification Teaching Mode. In *2024 13th International Conference on Educational and Information Technology (ICEIT)* (pp. 67-71). IEEE. <https://doi.org/10.1109/iceit61397.2024.10540856>
- Hapsari, T., Darhim, & Dahlan, J. A. (2018). Understanding and responding the students in learning mathematics through the differentiated instruction. In *Journal of Physics: Conference Series* (Vol. 1013, No. 1, p. 012136). IOP Publishing. <https://doi.org/10.1088/1742-6596/1013/1/012136>
- Hasan, H., Lesmawan, I. W., & Suastra, I. W. (2024). Implementasi Kurikulum Merdeka Pada Sekolah Dasar Systematic Literature Review. *Equilibrium: Jurnal Pendidikan*, 12(3), 295–305. <https://doi.org/10.26618/equilibrium.v12i3.15652>
- Hernández, R. V. R., Mendoza, A. L., & Hernández, R. S. (2024). Perceived instructor presence, interactive tools, student engagement, and satisfaction in hybrid education post-COVID-19 lockdown in Mexico. *Heliyon*, 10 (6), e27342. <https://doi.org/10.1016/j.heliyon.2024.e27342>
- Hoang, D. T. N., & Hoang, T. H. (2022). Ready or not? An exploration of university students' online learning readiness and intention to use during COVID-19 pandemic. *E-learning and Digital Media*, 20(5), 442-459. <https://doi.org/10.1177/20427530221117330>
- Holisoh, A., Nurhalimah, N., & Hamda, N. (2023). Analysis of the benefits of using e-modules as distance learning media: can it help students improve cognitive and affective aspects of students?. *Gema Wiralodra*, 14(2), 592-597. <https://doi.org/10.31943/gw.v14i2.313>
- Ismaya, E., & Yusritawati, I. (2023). Analisis Penerapan Kurikulum Merdeka dalam Meningkatkan Kemampuan Representasi Matematis Siswa. *Indo-MathEdu Intellectuals Journal*, 4(2), 90–98. <https://doi.org/10.54373/imeij.v4i2.123>

- Koimah, S. M., Zahra, N. A., Prasitini, E., Sasmita, S. K., & Sari, N. (2024). Implementasi Pembelajaran Berdiferensiasi untuk Memenuhi Kebutuhan Belajar Siswa yang Beragam. *Jurnal Ilmu Sosial Dan Budaya Indonesia*, 2(2), 58–66. <https://doi.org/10.61476/49j96838>
- Lapets, A. (2012). *Accessible integrated formal reasoning environments in classroom instruction of mathematics*. Computer Science Department, Boston University. <https://open.bu.edu/handle/2144/11403>
- Loi, C. K., Lim, J. M.-H., & Suki, N. (2024). Exploring University Students' Online Learning Readiness: A Mixed Methods Study of Forced Online Learning. *Journal of Language and Education*, 10(1 (37)), 49-67. <https://doi.org/10.17323/jle.2024.16016>
- Loureiro de Lima, G., Lutaif Bianchini, B., & Gomes, E. (2019). Comparação entre a teoria das Situações Didáticas de Brousseau e a Matemática no Contexto das Ciências de Camarena
Comparison between Brousseau's Theory of Didactic Situations and Mathematics in the Context of Camarena Sciences. *Educação Matemática Pesquisa: Revista Do Programa de Estudos Pós-Graduados Em Educação Matemática*, 21(5). <https://doi.org/10.23925/1983-3156.2019v21i5p151-161>
- Macharia, N. (2023). TAM's perceived usefulness influence on social network site preference for accessing reproductive health information among university students. *International Research Journal Of Modernization In Engineering Technology and Science*, 5(7), 3289-3300. <https://doi.org/10.56726/irjmets43586>
- Magalhães, P. J., & Teixeira, J. M. (2014). Um pouco da Teoria das Situações Didáticas (TSD) de Guy Brousseau Some of the theory of didactic situations (tsd) Guy Brousseau. *Zetetiké*, 21(1), 155-168. <https://www.fe.unicamp.br/revistas/ged/zetetike/article/view/4327>
- Maier, U., & Klotz, C. (2022). Personalized feedback in digital learning environments: Classification framework and literature review. *Computers & Education: Artificial Intelligence*, 3, 100080. <https://doi.org/10.1016/j.caeai.2022.100080>
- Manasrah, A., Masoud, M., Jaradat, Y., Jannoud, I., & Alheyasat, O. (2024). Ready, Click, Go! Evaluating the Readiness and Usability of an E-learning Portal from Students' Point of View. *The Eurasia Proceedings of Educational and Social Sciences*, 33, 112-120. <https://doi.org/10.55549/epess.1413347>
- Mangala, M. A., Nyanasuryanadi, P., & Suherman, H. (2024). Innovative Learning Using E-Modules. *Journal of Education Technology Information Social Sciences and Health*, 3(1), 550-557. <https://doi.org/10.57235/jetish.v3i1.1983>
- Mangiante-Orsola, C., Perrin-Glorian, M.-J., & Strømskag, H. (2018). Theory of didactical situations as a tool to understand and develop mathematics teaching practices. *Annales de Didactique et de Sciences Cognitives, Special issue*, 145–174. <https://doi.org/10.4000/adsc.334>
- Maphumulo, T., & Biccard, P. (2024). Mainstream Primary School Mathematics Classrooms. *Unnes Journal of Mathematics Education*, 13(1), 55. <https://doi.org/10.15294/ccwb1a43>
- Mardhatillah, M., & Suharyadi, S. (2023). Differentiated Instruction: Challenges and Opportunities in EFL Classroom. *Journal of English Language Teaching and Linguistics*, 8(1), 69. <https://doi.org/10.21462/jeltl.v8i1.1022>
- Marlina, D. (2020). *Strategi pembelajaran berdiferensiasi di sekolah inklusif* (Edisi ke-1, Cetakan Desember 2020). Cv. Afifa Utama.

- Martin, A. J., & Dowson, M. (2009). Interpersonal Relationships, Motivation, Engagement, and Achievement: Yields for Theory, Current Issues, and Educational Practice. *Review of Educational Research*, 79(1), 327–365. <https://doi.org/10.3102/0034654308325583>
- Martin, L. E., & Mulvihill, T. M. (2022). Voices in Education: Successful Professional Development for Educators: What Does It Look Like and Who Should Be Involved?. *The Teacher Educator*, 58(1), 1–14. <https://doi.org/10.1080/08878730.2023.2145716>
- Masjudin, M. (2024). Strengthening 21st Century Skills Through an Independent Curriculum In Mathematics Education In Indonesia: Challenges, Potential, And Strategies. *International Journal of Applied Science and Sustainable Development (IJASSD)*, 6(2), 92–113. <https://doi.org/10.36733/ijassd.v6i2.9087>
- Matematiksel, Ö., Yaşatılması, S., Erdoğan, A., & Özdemir Erdoğan, E. (2013). Didaktik Durumlar Teorisi Işığında İlköğretim. In *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD) Cilt* (Vol. 14).
- Memon, F. N., & Memon, S. N. (2025). *Digital divide and equity in education: Bridging gaps to ensure inclusive learning. In Impact of Digitalization on Education and Social Sustainability* (pp. 107-130). IGI Global. <https://doi.org/10.4018/979-8-3693-1854-6.ch004>
- Mirawati, I. G. A., Suwastini, N. K. A., Haryanti, N. D., & Jayantini, I. G. A. S. R. (2022). Differentiated instructions: Relevant studies on its implementation. *Prasi*, 17(1), 11-21. <https://doi.org/10.23887/prasi.v17i1.41867>
- Mulia, A. C., Sa'dijah, C., & Susanto, H. (2024). Implementasi Asesmen Berbasis Open-Ended Mathematics Problems Pada Siswa Smp Yang Mendukung Kurikulum Merdeka [Implementation of an Open-Ended Based Assessment With Middle School Mathematics Students That Supports the Merdeka Curriculum]. *JOHME: Journal of Holistic Mathematics Education*, 8(1), 1-17. <https://doi.org/10.19166/johme.v8i1.7721>
- Niu, N. (2009). On the Principles of Differentiated Instruction. *Journal of Lincang Teachers' College*.
- Obioma, D. M. N. C. (2023). Unlocking Potential: The Crucial Link between School Infrastructure and Educational Quality. *International Journal of Research and Innovation in Social Science*, 7(9), 404-413. <https://doi.org/10.47772/ijriss.2023.70934>
- OECD. (2023). *Shaping Digital Education: Enabling Factors for Quality, Equity and Efficiency*. OECD Publishing. <https://doi.org/10.1787/bac4dc9f-en>
- Oquendo, A. M., & Macancela, L. E. M. (2017). Las situaciones prácticas en el proceso de enseñanza aprendizaje de las matemáticas. *Revista Ciencias Pedagógicas e Innovación*, 4(1), 93-100. <https://doi.org/10.26423/RCPI.V4I1.121>
- Padmavathi, M. (2017). Preparing teachers for technologybased teaching-learning using TPACK. *Journal on School Educational Technology*, 12(3), 1-9. <https://doi.org/10.26634/JSCH.12.3.10384>
- Pawar, R. B., & Dhawale, V. (2025). A Comparative Analysis of Online Learning and Traditional Learning: Towards a Hybrid Learning Model. *Indian Scientific Journal of Research in Engineering and Management*, 09(01), 1–9. <https://doi.org/10.55041/ijsrem40711>
- Pettalongi, S. S., Londol, M. M., & Umboh, S. E. (2024). Disparities in Digital Education: Socioeconomic Barriers to Accessing Online Learning Resources. *International Journal of Social and Human.*, 1(3), 181–189. <https://doi.org/10.59613/be6gdv98>

- Prast, E., Weijer-Bergsma, E., Kroesbergen, E., & Luit, J. (2018). Differentiated instruction in primary mathematics: Effects of teacher professional development on student achievement. *Learning and Instruction*, 54, 22–34. <https://doi.org/10.1016/J.LEARNINSTRUC.2018.01.009>
- Putri, W. F., Hidayanti, D. N., Muzhafran, M., & Ramadhan, I. F. (2024). Analisis Problematika Kurikulum Merdeka pada Pembelajaran Matematika di SDN 012 Babakan Ciparay Kota Bandung. *Jurnal Riset Rumpun Matematika dan Ilmu Pengetahuan Alam*, 3(1), 119-128. <https://doi.org/10.55606/jurrimipa.v3i1.2288>
- Rahayu, A., & Rosti, R. (2023). Interactive Digital Teaching Module Based on Differentiated Instruction and Its Impact on Students' Problem-Solving Skills. *Jurnal Penelitian Pendidikan IPA*, 9(SpecialIssue), 1128-1136. <https://doi.org/10.29303/jppipa.v9ispecialissue.5072>
- Ramdhani, S., Nirmala, S. D., & Nurcahyono, N. A. (2025). Challenges in Online Mathematics Education for Elementary Schools: A Teacher's Perspective from Indonesia. *Indonesian Journal of Educational Development (IJED)*, 6(1), 109-123. <https://doi.org/10.59672/ijed.v6i1.4640>
- Ratnawati, K., Artini, N. L. P., & Kusuma, I. P. I. (2024). Interactive E-Modules Assisted By Google Sites in Efl: Its Effect on Students'critical Thinking and Learning Engagement. *Indonesian Journal of Educational Development (IJED)*, 5(2), 194-207. <https://doi.org/10.59672/ijed.v5i2.4032>
- Rifqi, M. S. (2024). Exploring Challenges of Differentiated Instruction in English Foreign Language Classroom. *LET: Linguistics, Literature and English Teaching Journal*, 14(1), 77-97. <https://doi.org/10.18592/let.v14i1.12174>
- Rønning, F. (2021). Opportunities for language enhancement in a learning environment designed on the basis of the theory of didactical situations. *ZDM–Mathematics education*, 53(2), 305-316. <https://doi.org/10.1007/S11858-020-01199-X>
- Saenboonsong, S., & Poonsawad, A. (2024). The Development of Students' Creative Problem-Solving Skills Through Learning Model in Gamification Environment Together with Cartoon Animation Media. *Journal of Education and Learning*, 13(2), 138-148. <https://doi.org/10.5539/jel.v13n2p138>
- Sanmas, M., Qadir, A., Nahria, N., & Laili, I. (2024). The Role of Interpersonal Communication in Enhancing Teamwork Effectiveness in the Digital Era. *LITERATUS*, 5(2). <https://doi.org/10.37010/lit.v5i2.1503>
- Schaeffer, M. W., Rozek, C. S., Maloney, E. A., Berkowitz, T., Levine, S. C., & Beilock, S. L. (2021). Elementary school teachers' math anxiety and students' math learning: A large-scale replication. *Developmental Science*, 24(4), e13080. <https://doi.org/10.1111/desc.13080>
- Setambah, M. A. B., Saad, M. I. M., & Adnan, M. (2024). A comprehensive synthesis of differentiated instruction approaches in mathematics. *LUMAT: International Journal on Math, Science and Technology Education*, 12(4), 1-18. <https://doi.org/10.31129/LUMAT.12.4.2371>
- Shaya, N. (2024). *Assessment of Student Readiness, Willingness and Acceptance for Effective Transitioning Toward Online Instruction* (pp. 35–47). Springer International Publishing. https://doi.org/10.1007/978-3-031-49393-5_6
- Smets, W., & Struyven, K. (2018). Aligning with complexity: system-theoretical principles for research on differentiated instruction. *Frontline Learning Research*, 6(2), 66–80. <https://doi.org/10.14786/flr.v6i2.340>
- Suastika, I. K. (2023). The Practicality and Effectiveness of E-Modules with an Inquiry Approach in Geometry Learning Courses for Elementary School Teacher Education Students. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, 7(4), 1118. <https://doi.org/10.31764/jtam.v7i4.16543>

- Sun, D., Wang, J., Yang, L., Chou, K.-I., Song, Z., & Zheng, Z. (2024, November 25). *AI-driven feedback for enhancing students' mathematical problem-solving: The ScaffoldiaMyMaths system*. In *Proceedings of the 32nd International Conference on Computers in Education (ICCE 2024)*. Asia-Pacific Society for Computers in Education. <https://doi.org/10.58459/icce.2024.5054>
- Sun, X., & Yusof, S. M. (2024). Implementation of and challenges in differentiated L2 language instruction: A systematic literature review (2014-2023). *Salud, Ciencia y Tecnología-Serie de Conferencias*, 3, 1249. <https://doi.org/10.56294/sctconf2024.1249>
- Syaiful, S., Salam, U., & Maria, H. T. (2023). Pengembangan E-Modul Interaktif Dalam Meningkatkan Hasil Belajar Sistem Ekskresi Pada Manusia. *Academy of Education Journal*, 14(2), 854–872. <https://doi.org/10.47200/aoej.v14i2.1936>
- Tamba, K. P. (2022, November). Digital task design using theory of didactical situation. In *AIP Conference Proceedings* (Vol. 2566, No. 1, p. 020031). AIP Publishing LLC. <https://doi.org/10.1063/5.0114199>
- Tamaro, R., & D'Alessio, A. (2016). Teacher Training and Digital Competence: A Pedagogical Recommendation. *International Journal of Digital Literacy and Digital Competence*, 7(2), 1–10. <https://doi.org/10.4018/IJDLDC.2016040101>
- Tomlinson, C. A. (2014). *The differentiated classroom: Responding to the needs of all learners* (2nd ed.). ASCD.
- Tomlinson, C. A., & Moon, T. R. (2013). *Assessment and student success in a differentiated classroom*. Alexandria, VA: Association for Supervision and Curriculum Development (ASCD).
- Wahyudin, D., Subkhan, E., Malik, A., Hakim, M. A., Sudiapermana, E., Alhapip, L., Anggraena, Y., Maisura, R., Amalia, N., & Solihin, L. (2024). Kajian Akademik Kurikulum Merdeka. Jakarta: Pusat Kurikulum Dan Pembelajaran, Badan Standar, Kurikulum, Dan Asesmen Pendidikan, Kementerian Pendidikan, Kebudayaan, Riset Dan Teknologi.
- Wahyuni, S., Iqbal, M., & Baharuddin. (2024). Evaluasi efektivitas penerapan kurikulum merdeka dalam meningkatkan hasil belajar dan keterampilan literasi siswa sekolah dasar. *Idarah Tarbawiyah: Journal of Management in Islamic Education*, 5(3), 360–368. <https://doi.org/10.32832/itjmie.v5i3.16736>
- Whiting, J., Haniya, S., & Evans, J. R. (2023). *Conceptualizing Recursive Feedback in Digital Learning Spaces* (pp. 152–164). IGI Global. <https://doi.org/10.4018/978-1-6684-5124-3.ch008>
- Winangun, I. M. A. (2024). Interactive E-Modules with Cases of Local Wisdom in Learning Animal Diversity to Improve Student Learning Outcomes. *Jurnal Imiah Pendidikan Dan Pembelajaran*, 8(1), 118–124. <https://doi.org/10.23887/jipp.v8i1.69028>
- Xu, Q. (2024). The Impact of New Media Technology Applications on Educational Equity in Rural Areas. *Education Journal*, 13(5), 284–293. <https://doi.org/10.11648/j.edu.20241305.15>
- Yanti, Y., Juliansyah, M. E., Erlina, E., Hijriah, U., & Irfani, B. (2024). Peranan Guru dalam Mewujudkan Pendidikan Karakter Era Kurikulum Merdeka. *Thawalib: Jurnal Kependidikan Islam*, 5(2), 513–524. <https://doi.org/10.54150/thawalib.v5i2.497>
- Zulkarnaen, R., Darmawan, B. A., & Ruli, R. M. (2022). PENGEMBANGAN LEMBAR KERJA SISWA DALAM MATERI MATEMATIKA PADA KELAS VIII BERBASIS THEORY OF DIDACTICAL SITUATION. *Teorema: Teori Dan Riset Matematika*, 7(2), 365. <https://doi.org/10.25157/teorema.v7i2.7322>

Λαμπρόπουλος, Γ., & Sidiropoulos, A. (2024). Impact of Gamification on Students' Learning Outcomes and Academic Performance: A Longitudinal Study Comparing Online, Traditional, and Gamified Learning. *Education Sciences*, 14(4), 367. <https://doi.org/10.3390/educsci14040367>

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