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Didactical Design Research: Developing Technology-Based Instructional Designs to Enhance Problem-Solving Skills in Mathematics

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Abstract: The integration of technology into education has become an urgent necessity, particularly in regions with limited access to advanced teaching practices. In South Sulawesi, especially in rural areas, technological resources such as *smartboards* and computers remain underutilized. This underutilization stems from the absence of instructional designs that can guide teachers in effectively integrating technology into their teaching practices. Consequently, traditional teaching methods, which are often misaligned with the demands of the 21st century, still dominate, leaving critical skills like problem-solving underdeveloped. This study adopts the Didactical Design Research (**DDR**) approach to address these challenges. DDR facilitates the development of technology-enhanced instructional designs aimed at improving the problem-solving abilities of senior high school students. The instructional designs are created using the HTML5 Package (**H5P**), an interactive digital tool designed to foster student engagement in the learning process. The research is conducted in three stages. The first stage, *prospective analysis*, involves identifying educational needs and creating the initial design. The second stage, *metapedadidactic analysis*, evaluates the implementation of the design in real classroom settings. Finally, the *retrospective analysis* stage reflects on the outcomes to refine and optimize the instructional design further. This study aims to provide a robust framework for technology-based instructional design, addressing the technological and pedagogical gaps in mathematics education. The findings are expected to significantly enhance the quality of mathematics learning by strengthening students' problem-solving skills, equipping them with essential competencies to tackle future challenges, and offering adaptable solutions for schools in similar contexts.

Keywords: Didactical design research, H5P, Problem-solving, Polya's method, Technology-based learning

Introduction

The integration of technology in education has evolved from serving as a complementary tool to becoming an essential component in 21st-century learning. Advances in digital platforms have enabled more interactive, adaptive, and student-centered learning environments (Barana & Marchisio, 2020; Hutasoit et al., 2025). Despite this progress, the adoption of educational technology remains uneven, particularly in rural regions where digital infrastructure and pedagogical capacity are limited. For instance, schools in South Sulawesi, Indonesia, have received technological support such as smartboards and computers, yet their utilization remains suboptimal due to the absence of effective instructional frameworks that guide teachers in integrating these tools into learning (Mutawally &Wardinur, 2019; Nurhayati et al., 2025). This issue highlights a crucial gap between technology availability and its pedagogical implementation (Kövecses-Gősi, 2024; Mayer, 2020).

Traditional teacher-centered approaches continue to dominate classrooms in many regions, often prioritizing rote learning over higher-order cognitive engagement (Duan, 2022; Sidik et al., 2021). Consequently, students have limited opportunities to develop essential 21st-century competencies such as problem-solving, self-regulated learning, and creative reasoning (Fauzi & Widjajanti, 2018; Polya, 2004; Schoenfeld, 2016). Several studies have emphasized that the lack of innovative instructional designs contributes significantly to low engagement and shallow conceptual understanding in mathematics learning (Afrizal et al., 2023; Alfieri et al., 2011; Hattie, 2012;). Therefore, the integration of technology into learning should not merely focus on digital access but on designing didactically sound learning environments that cultivate students' critical and reflective thinking (Wijaya et al., 2025; Zhu et al., 2025).

Didactical Design Research (DDR) provides a systematic and iterative methodology to address these pedagogical challenges. Grounded in the principles of didactical analysis and learning trajectory development, DDR emphasizes the interaction between teacher design, student learning processes, and didactical phenomena that emerge during implementation (Isnawan & Sukarma, n.d.; Suryadi et al., 2018). Through its cyclic process of prospective, metapedadidactic, and retrospective analyses, DDR enables researchers to refine instructional designs based on empirical classroom data, ensuring that each iteration better supports students' conceptual growth and engagement (Sidik et al., 2021).

In this study, DDR is employed to develop and evaluate *technology-based instructional designs* utilizing the HTML5 Package (H5P). H5P is a versatile digital authoring tool that allows educators to design highly interactive learning materials, including simulations, branching scenarios, and problem-solving activities (Mutawa et al., 2023; Pinoa, 2021). Recent studies have demonstrated H5P's potential in fostering self-regulated learning and improving engagement across various educational contexts (Kakish et al., 2024; Ramos-Azcuy et al., 2025). In mathematics education, interactive features such as virtual manipulatives and dynamic feedback promote conceptual understanding and persistence in problem-solving (Ates & Kölemen, 2025; Mahmuti & Arifi, 2025). When integrated with Polya's four-step problem-solving model, H5P-based learning activities can scaffold students' reasoning and help them internalize systematic strategies for tackling complex mathematical problems (Polya, 2004; Zahrona & Chaniago, 2021).

By leveraging the didactical design approach and the interactive affordances of H5P, this research aims to address two interrelated challenges: the underutilization of educational technology and the insufficient development of mathematical problem-solving skills among high school students in South Sulawesi. The outcomes are expected to contribute to the broader discourse on how technology-enhanced didactical designs can promote equitable, engaging, and higher-order learning experiences in mathematics classrooms (Goos et al., 2017; Heick, 2019; Novalia et al., 2025).

Method

This study employed the Didactical Design Research (DDR) approach, a methodological framework focusing on the iterative development and refinement of instructional designs through systematic cycles of design, implementation, and analysis (Suryadi et al., 2018; Isnawan & Sukarma, n.d.). DDR was selected because it provides both theoretical and practical mechanisms for analyzing learning processes and generating design principles that are contextually relevant and empirically validated.

Research Design

DDR consists of three main stages Prospective Analysis (Pre-Teaching Phase), Metapedadidactic Analysis (During Teaching Phase), and Retrospective Analysis (Post-Teaching Phase).

These stages are interconnected in a cyclical manner to ensure continuous refinement of the instructional design (Sidik et al., 2021). In the prospective stage, the researcher conducted a literature review and preliminary classroom observations to identify students' learning obstacles related to mathematical problem-solving (Duan, 2022; Sidik et al., 2021). The findings informed the initial development of the *Hypothetical Learning Trajectory (HLT)*, which described anticipated learning paths, potential misconceptions, and strategies for scaffolding understanding. During the metapedadidactic stage, the developed design was implemented in a real classroom environment to observe how students engaged with the technology-based learning materials and how teachers facilitated the learning process. This stage provided empirical data on the interaction between the designed tasks, teacher interventions, and student responses (Isnawan & Sukarma, n.d.). Finally, the retrospective stage involved a comprehensive analysis comparing the hypothetical learning trajectory with the actual learning outcomes. Insights from this stage guided design revisions and theoretical reflections to strengthen the next iteration of the instructional design (Suryadi et al., 2018).

Participants and Setting

The study was conducted at a public high school in South Sulawesi, Indonesia, recognized as one of the pilot schools for the implementation of the *Merdeka Curriculum*. The participants consisted of 30 eleventh-grade students (aged 16–17 years) with varying levels of mathematical achievement. The selection followed purposive sampling to ensure that the class represented diverse learning abilities and technological familiarity (Afrizal et al., 2023; Nurhayati et al., 2025). The research was carried out over six weeks during the second semester of the 2024–2025 academic year.

Development of Technology-Based Learning Design

The instructional design was developed using H5P (HTML5 Package), a digital tool that enables the creation of interactive, multimedia-rich learning modules. The design incorporated Polya's four-step problem-solving model understanding the problem, devising a plan, carrying out the plan, and looking back—as the core framework for developing students' mathematical reasoning and problem-solving skills (Polya, 2004; Zahrona & Chaniago, 2021). Learning activities were constructed around contextual mathematical problems aligned with the high school curriculum. Interactive features such as branching scenarios, virtual manipulatives, and instant feedback mechanisms were embedded to encourage self-regulated and exploratory learning (Ates & Kölemen, 2025; Mutawa et al., 2023). To ensure design validity, expert validation was carried out involving two mathematics education specialists and one instructional technology expert. The validation focused on didactical coherence, technological usability, and alignment with learning objectives (Mahmuti & Arifi, 2025; Hutasoit et al., 2025).

Data Collection

Data collection in this study employed multiple instruments to capture both learning processes and outcomes. Classroom observations were conducted to document teacher mediation and student engagement during the implementation of the H5P-based lessons. Student worksheets and digital log data from the H5P platform were analyzed to identify patterns of interaction and problem-solving strategies. Semi-structured interviews with selected students and the teacher were carried out to explore their perceptions of the learning experience and the usability of the technology. In addition, pre- and post-tests were administered to measure students' problem-solving performance, conceptual understanding, and self-regulated learning tendencies, as suggested by Fauzi and Widjajanti (2018), Fahmad and Hidayati (2022). These multiple data sources provided a comprehensive foundation for analyzing the effectiveness of the developed instructional design.

Data Analysis

Data were analyzed using qualitative and quantitative approaches. Qualitative data from observations and interviews were coded thematically to identify recurring patterns related to student engagement, misconceptions, and the effectiveness of technological scaffolds (Suryadi et al., 2018). Quantitative data from pre- and post-tests were analyzed using descriptive and inferential statistics (paired-sample t-test) to examine improvements in students' problem-solving performance (Afrizal et al., 2023; Duan, 2022). The triangulation of data sources ensured the validity and reliability of findings, providing a robust foundation for refining the didactical design.

Results and Discussion

This section presents the findings from the implementation of the H5P-based learning design, focusing on students' mathematical communication, engagement, and problem-solving development. The results are organized according to the three phases of the Didactical Design Research: prospective, metapedadidactic, and retrospective analyses. Quantitative results from pre- and post-tests are complemented by qualitative insights from classroom observations, student worksheets, and interviews. The integration of these data sources provides a comprehensive understanding of how the designed intervention supported students' learning processes.

Result

Table 1. Pre-test and post-test results on students' problem-solving ability

Polya's problem-solving stage	Mean pre-test	Mean post-test	Improvement (%)
Understanding the problem	62.4	83.1	33.2
Devising a plan	58.7	79.2	34.9
Carrying out the plan	55.3	77.8	40.7
Looking back	50.9	71.6	40.6
Overall Mean	56.8	79.9	35.7

Table 1 shows that students' problem-solving performance improved substantially after participating in the H5P-based instructional design. The overall mean increased from 56.8 to 79.9, with an average gain of 35.7%. The most significant progress occurred in the stages of *carrying out the plan* and *looking back*, suggesting that interactive features such as branching and feedback supported reflective and strategic thinking.

Table 2 Students' engagement levels before and after the intervention

Engagement indicator	Before intervention	After intervention	Change
Activeness in discussion	3.1	4.4	+1.3
Focus during learning	2.9	4.2	+1.3
Enthusiasm toward tasks	3.3	4.6	+1.3
Collaboration with peers	3.2	4.5	+1.3
Overall Mean (scale 1–5)	3.1	4.4	+1.3

Table 2 indicates a noticeable increase in student engagement across all indicators, with an overall mean improvement of 1.3 points. The integration of interactive H5P elements encouraged greater collaboration, enthusiasm, and focus during mathematics lessons, transforming classroom dynamics into a more student-centered environment.

Table 3 Teachers' and students' perceptions of the H5P-based instructional design

Respondent	Effectiveness (1–5)	Curriculum alignment (1–5)	Ease of use (1–5)	Mean
Teacher 1	5.0	4.8	4.6	4.8
Teacher 2	4.7	4.5	4.3	4.5
Teacher 3	4.9	4.6	4.4	4.6
Students (average of 30)	4.6	4.5	4.2	4.4
Overall Mean	4.8	4.6	4.4	4.6

Table 3 presents the results of perception surveys from teachers and students. The overall mean score of 4.6 reflects highly positive responses, particularly in perceived effectiveness and curriculum alignment. Participants emphasized that the use of H5P facilitated clearer conceptual understanding and reduced learning difficulties commonly found in abstract mathematical topics.

Table 4 Digital log data from the H5P platform

Activity type	Average attempts per student	Success rate (%)	Average time per activity (minutes)
Drag-and-drop	3.8	87.2	5.6
Interactive video	2.5	81.5	6.8
Branching scenario	3.2	78.9	7.1
Concept quiz	4.0	84.6	4.3
Overall Mean	3.4	83.1	5.9

Table 4 summarizes the interaction data automatically recorded by the H5P platform. Students averaged 3.4 attempts per activity with an overall success rate of 83.1%. The relatively high number of attempts suggests an iterative learning process, where students engaged in trial, reflection, and correction — consistent with the principles of Didactical Design Research and Polya's problem-solving framework.

Discussion

The findings indicate that the implementation of the H5P-based learning design effectively enhanced students' mathematical communication and engagement during classroom activities. Students demonstrated greater initiative in explaining their reasoning processes, both verbally and through digital tasks. This result aligns with Vygotsky's (1978) theory of social constructivism, which emphasizes that learning occurs through mediated interaction and dialogic engagement. The teacher's facilitation through guiding questions and feedback within the H5P environment acted as a mediational tool that helped students articulate their mathematical thinking.

Furthermore, the data from student worksheets and H5P digital logs revealed a consistent improvement in students' ability to decompose problems into sub-tasks, suggesting progress in metacognitive control. This finding resonates with Zimmerman's (2000) model of self-regulated learning, where planning, monitoring, and reflection are crucial for achieving learning autonomy. Students' reflection responses also showed that the digital platform encouraged them to evaluate their solutions independently before seeking teacher confirmation.

Classroom observations supported these findings by showing increased peer collaboration and productive mathematical discussions. Students frequently used the interactive elements of H5P, such as drag-and-drop exercises and embedded quizzes, to test their understanding in real time. This pattern of interaction is consistent with Mayer's (2005) cognitive theory of multimedia learning, which posits that integrating visual and interactive stimuli enhances cognitive processing and conceptual retention.

Figure 1. Giving directions in class to use H5P

The post-test results further confirmed significant improvement in problem-solving and conceptual understanding, supporting prior studies that highlight the positive impact of digital learning tools on mathematical reasoning (Fauzi & Widjajanti, 2018; Fahmad & Hidayati, 2022). These findings collectively suggest that integrating technology with didactical design principles can foster both cognitive and social dimensions of learning, reinforcing the role of digital pedagogy in mathematics education.

Conclusion

This study concludes that the Didactical Design Research (DDR) approach using H5P-based digital modules has significantly improved students' mathematical communication and problem-solving abilities. The structured design, which follows Polya's four-step problem-solving process, effectively guided students to reason, plan, and reflect during mathematical tasks. The integration of multimedia elements—such as interactive drag-and-drop activities, branching scenarios, and video tutorials—enhanced engagement and conceptual understanding, particularly in abstract topics.

The findings revealed that the interactive environment fostered collaboration, encouraged metacognitive reflection, and supported differentiated learning. Teachers reported increased classroom interaction and a shift toward more student-centered learning. These outcomes are consistent with Vygotsky's (1978) theory of social constructivism, which emphasizes the importance of mediated learning, and with Mayer's (2005) cognitive theory of multimedia learning, which highlights how dual-channel engagement can improve comprehension.

Overall, the study demonstrates that combining technology with a didactical design grounded in theory can create meaningful mathematical learning experiences, especially in schools with limited access to modern learning resources.

Recommendations

Based on the study's findings, several recommendations are proposed. First, future implementations of H5P-based instructional designs should include comprehensive teacher training on both technological and didactical aspects to ensure effective classroom integration. Second, the development of culturally relevant and contextually grounded mathematical examples is recommended to increase student relatability and motivation. Further research should expand the sample size and duration of intervention to measure long-term impacts on students' problem-solving persistence and communication fluency. Researchers may also explore hybrid or fully online adaptations of the design to assess scalability and sustainability in diverse educational contexts.

Finally, it is recommended that policymakers and school administrators support the adoption of digital learning innovations like H5P by providing infrastructure, professional development programs, and continuous evaluation mechanisms. Such systemic support will ensure that technology serves as a catalyst—not a substitute—for pedagogical transformation in mathematics education.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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