JPPIPA 11(9) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

A Needs Analysis of Problem-Based Learning Media Using the Design Thinking Framework to Improve Critical Thinking

Sri Rahayu[1], Aryo Andri Nugroho[1*], Nizaruddin[1]

[1] Universitas PGRI Semarang, Indonesia

Received: June 29, 2025
Revised: August 04, 2025
Accepted: September 25, 2025
Published: September 30, 2025

Corresponding Author:
Aryo Andri Nugroho
aryoandri@upgris.ac.id

DOI: 10.29303/jppipa.v11i9.12415

Abstract: Low mathematics achievement in Indonesian secondary schools persists despite ongoing curriculum reforms. This study employed a Design Thinking–guided mixed-method inquiry to analyse instructional needs and co-create a multimedia Problem-Based Learning (PBL) model that fosters critical thinking. Three purposively selected schools in Batam contributed three mathematics teachers and forty-two students. Data were gathered through two rounds of semi-structured interviews, classroom observations, and Google-Form questionnaires. Qualitative coding during the Empathise and Define stages revealed four central issues: limited transfer of concepts to problem contexts, weak foundational mastery, mismatch between learning media and student preferences, and scarce collaborative support. Only 7.2 % of students felt competent, whereas 83.3 % acknowledged frequent computational errors and 80 % were unable to apply formulas. Students preferred group discussion (67.7 %), peer tutoring (51.6 %), and audio-visual media (45.2 %). In the Ideate stage, a PBL sequence aligned with the TPACK framework was prototyped and pilot-taught in each school. Observation indicated that 67.7 % of learners participated actively in group problem-solving, while post-lesson feedback showed 74.4 % experienced clearer conceptual understanding when multimedia and peer support were combined. Teachers reported improved lesson flow and greater responsiveness to heterogeneous ability levels. The study concludes that Design Thinking, coupled with media-rich PBL, can realign pedagogy with stakeholder needs, strengthen critical-thinking dispositions, and serve as a replicable model for mathematics instruction in similar contexts. Future work should examine long-term learning gains, scalability across diverse regions, and professional development structures required to sustain technology-enhanced PBL adoption. Such evidence will clarify policy guidelines and funding priorities for equitable implementation nationwide.

Keywords: Design Thinking; Problem-Based Learning; Critical thinking; Mathematics education; Multimedia

Introduction

International and national assessments have persistently revealed Indonesia's struggle to achieve adequate mathematics performance, as evidenced by the country's low ranking—69th out of 80 participants—in the 2022 PISA and TIMMS results, illustrating a marked gap with neighboring countries such as Malaysia, Thailand, and Singapore (OECD, 2022). This persistent underachievement not only points to students' limited interest but also signals inadequate comprehension, reading abilities, and low engagement in mathematics classrooms (Leung et al., 2019). The prevalence of monotonous teaching methods has been found to

How to Cite:
Rahayu, S., Nugroho, A. A., & Nizaruddin. (2025). A Needs Analysis of Problem-Based Learning Media Using the Design Thinking Framework to Improve Critical Thinking. *Jurnal Penelitian Pendidikan IPA*, *11*(9), 63–71. https://doi.org/10.29303/jppipa.v11i9.12415

further erode students' learning experiences and diminish their confidence in developing mathematical competencies, thus aggravating negative attitudes towards the subject (Amir et al., 2021; Harsy et al., 2020). Such negative experiences ultimately lead to heightened anxiety and a lack of perceived challenge, making it increasingly difficult for students to meaningfully engage with mathematics (Afriansyah et al., 2021; Dalitz, 2021). Consequently, a growing body of research highlights the need for attractive learning media and interactive classroom dynamics as essential strategies to boost student motivation and improve mathematics learning outcomes (Hikmah, 2021; Lombardi et al., 2019; Matsun et al., 2019). These findings collectively indicate a pressing need for transformative innovations in mathematics instruction across Indonesian schools.

The critical need for innovative instructional models is most apparent in addressing students' critical thinking and problem-solving abilities, which are central to effective mathematics education (Brown, 2008; Dunne & Martin, 2006). Design thinking has gained recognition as a cognitive and structured approach that enables both students and educators to develop creative solutions to complex and ambiguous challenges (Lindberg et al., 2010). Rather than prioritizing solely the learning outcomes or end products, design thinking emphasizes multidisciplinarity and encourages learners to engage with problems from diverse perspectives, facilitating meaningful collaborative and real-world experiences (Glen et al., 2014; Lindberg et al., 2010). Studies demonstrate that design thinking is uniquely positioned to address complex, ill-defined problems that are common in daily life yet rarely solved through traditional classroom routines (Dolak et al., 2013; Ray, 2020). Moreover, creativity—regarded as a crucial 21st-century competency for both teachers and students—is cultivated through design thinking, yet often remains underrepresented in day-to-day classroom activities due to systemic challenges (Root-Bernstein & Root-Bernstein, 2016). In summary, the adoption of design thinking in education is poised to play a transformative role in promoting creativity and critical thinking as core educational outcomes, thus responding to the complex demands of modern learning environments.

The integration of design thinking into educational practice has attracted significant attention due to its human-centered, adaptable frameworks that support both student and teacher development (Kijima et al., 2021). Frameworks such as IDEO's three-stage process—comprising inspiration, ideation, and implementation—and Stanford d.School's five-stage model—empathize, define, ideate, prototype, and test—have become widely adopted in global educational reform efforts. These models emphasize structured yet flexible guidance for tackling everyday academic challenges, ensuring that problem-solving skills are systematically developed through real-life applications (Dolak et al., 2013). The evolution of design thinking frameworks over time, including Liedtka's four-stage process of What is? What if? What wows? What works?, further illustrates the growing acceptance of these models in diverse educational contexts (Kijima et al., 2021). Evidence shows that applying these frameworks in classroom environments not only stimulates innovative idea generation and reflection on multiple viewpoints, but also ensures instructional design is closely aligned with the authentic needs and insights of students (Glen et al., 2014). Thus, incorporating design thinking frameworks into teaching strategies is seen as a progressive movement towards cultivating dynamic and effective educational experiences.

The novelty and significance of this research stem from its application of design thinking analysis within the school learning environment, which highlights the importance of thoroughly assessing students' comprehension, the systems by which they learn, and their expectations regarding instructional media (Kijima et al., 2021). Utilizing the design thinking approach is not only relevant but also essential for accurately identifying the most effective learning methods and media to foster critical thinking skills in everyday academic activities (Brown, 2008; Dunne & Martin, 2006). Through systematic needs analysis, educators are enabled to transcend traditional, teacher-centered pedagogies, shifting instead to learner-centered strategies that emphasize active engagement and the development of problem-solving competencies (Root-Bernstein & Root-Bernstein, 2016). This research directly addresses the ongoing call for educational innovation by offering empirical evidence on the effective application of design thinking in enhancing mathematics learning outcomes. Findings from this study underscore the necessity of aligning teaching practices with students' authentic experiences and aspirations, thereby laying the groundwork for the cultivation of critical thinking as a core component of 21st-century education (Brown, 2008). Consequently, this work delivers timely and relevant insights for advancing instructional design practices in Indonesian educational contexts.

In the realm of mathematics education, persistent difficulties encountered by Indonesian students underscore the necessity of adopting collaborative and student-centered strategies such as design thinking to address learning gaps (Leung et al., 2019; OECD, 2022). By employing the design thinking framework in this study, comprehensive needs assessments were conducted with both teachers and students across three senior high schools in Batam, utilizing direct interviews and structured questionnaires to capture diverse perspectives. The data revealed that 80% of students struggled with applying mathematical concepts and formulas during daily lessons, while 67% of teachers voiced concerns regarding students' sustained attention and incomplete mastery of core mathematical material (Dalitz, 2021; Harsy et al., 2020). Additionally, interviews indicated that teachers often mitigated these challenges by offering individualized exercises, differentiated instruction, and supplementary resources including both printed and digital media (Lombardi et al., 2019; Matsun et al., 2019). These findings collectively suggest that contextually relevant and engaging instructional media are pivotal for motivating students and enhancing mathematics achievement. Ultimately, the evidence demonstrates a critical need for ongoing innovation in instructional strategies and resources to ensure meaningful student engagement and improved conceptual understanding in mathematics education.

Further insights from in-depth student interviews underscore the diverse and significant challenges present within mathematics classrooms, revealing that only 7.2% of respondents claimed to fully master mathematical concepts, while a striking 83.3% reported difficulties in comprehension and accuracy (Afriansyah et al., 2021; Lombardi et al., 2019; Matsun et al., 2019). Follow-up surveys confirmed that the majority of students required considerable support from both teachers and peers, with 74.2% expressing confidence only when assistance was available and 67.7% identifying group discussions as a primary source of motivation for learning (Hikmah, 2021). Students also articulated strong preferences for diverse media, with 64.5% favoring printed materials and 45.2% opting for multimedia tools, highlighting the necessity for media-rich and adaptive instructional approaches in the classroom (Amir et al., 2021; Brown, 2008; Leung et al., 2019). These findings reinforce the importance of differentiated and collaborative teaching strategies, demonstrating that responsive pedagogy is fundamental to fostering student engagement and critical thinking. In conclusion, student-driven data validate the call for adaptive and collaborative learning environments as vital to supporting mathematics achievement in Indonesia.

Synthesizing perspectives from both teachers and students, this study affirms the value of integrating design thinking with instructional models such as Problem-Based Learning (PBL) and Technological Pedagogical Content Knowledge (TPACK) to cultivate critical thinking in mathematics education (Glazer, 2001). Within the schools observed, educators predominantly utilized a blend of discussion, lecture, and PBL approaches, further supplemented by digital media and collaborative learning exercises to address knowledge gaps (Lindberg et al., 2010). Empirical evidence from this research indicates that media-supported PBL strategies effectively increase student motivation, with 51.6% of students benefiting from peer tutoring and 54.8% preferring a mix of lectures and independent assignments (Lombardi et al., 2019; Matsun et al., 2019). These approaches were also found to foster authentic learning experiences, encouraging communication, problem-solving, and teamwork as essential 21st-century competencies (Hikmah, 2021). In conclusion, the integration of design thinking with dynamic instructional media emerges as a crucial driver for enhancing students' critical thinking abilities and academic outcomes, supporting ongoing pedagogical innovation in Indonesia's mathematics education landscape.

Method

Research Design

This study adopted a Design Thinking–based mixed-method design to identify, analyse, and address instructional needs that inhibit the development of students' critical-thinking skills in mathematics. Design Thinking provides a systematic, human-centred framework that progresses through five iterative stages—Empathise, Define, Ideate, Prototype, and Test—allowing researchers to cycle seamlessly between qualitative exploration and quantitative confirmation of emergent insights (Dunne & Martin, 2006).

Context and Participants

Three upper-secondary schools in Batam, Indonesia, were selected purposively to capture heterogeneity in demographic and institutional profiles. One mathematics teacher and a cohort of students from each school participated, producing a total sample of 3 teachers and 42 students (Table 1).

Table 1. Study participants

School	Sub-District	Teachers (n)	Students (n)
SMK Real Informatika	Batam Kota	1	7
SMA Putra Batam	Batu Aji	1	16
MAN Manbaul Hidayah	Nongsa	1	19

Instruments

Two rounds of semi-structured interviews and online questionnaires (Google Forms) were developed separately for teachers and students: Teacher Interview & Questionnaire (TIQ), *Round 1* explored perceived classroom challenges and student difficulties (14 Nov

2024). *Round 2* probed instructional strategies, available facilities, and preferred media (26 Nov 2024); and Student Interview & Questionnaire (SIQ), *Round 1* (19 items) captured motivation, interest, and conceptual mastery (14 Nov 2024). *Round 2* (5 items) examined preferred learning modes, media, and peer-support mechanisms.

Questionnaire items combined Likert-type scales, multiple choice, and open-ended prompts. Instrument face validity was confirmed via expert review by two mathematics-education specialists; internal consistency for scaled items met an acceptable Cronbach's $\alpha \geq 0.78$.

Data-Collection Procedure

Data collection aligned with the Empathise stage: Permission & Ethics, Written consent was obtained from school principals, teachers, students, and parents. Identities were pseudonymised and data stored on password-protected drives; Empathise Phase, Researchers conducted on-site classroom observations, followed by TIQ and SIQ administration. All interviews were audio-recorded and transcribed verbatim; Define Phase, Interview transcripts and questionnaire results were coded to isolate recurrent pain-points, then synthesised into *Point-of-View* (POV) statements for each user group; Ideate Phase, A researcher–teacher focus group brainstormed solutions; the highest-ranking idea combined Problem-Based Learning (PBL) with a TPACK-aligned multimedia package; Prototype Phase, a low-fidelity PBL lesson plan and supporting digital media were constructed; and Test Phase, the prototype was pilot-taught in one lesson per school; observational field notes and immediate student feedback were gathered to inform iterative refinement.

Data Analysis

Quantitative data from closed-ended questionnaire items were analysed descriptively (frequencies and percentages) using SPSS 25. *Qualitative data*—open-ended responses, interview transcripts, and field notes—were thematically coded with NVivo 14. Codes were triangulated across data sources, and peer debriefing was employed to enhance credibility. Emergent themes informed movement between Design Thinking stages, ensuring that each subsequent action directly addressed user-verified needs.

Trustworthiness and Rigour

Credibility was strengthened through *methodological triangulation* (interview × questionnaire × observation) and *member checking* with participants after each stage. *Transferability* was supported by rich contextual description; *dependability* and *confirmability* were established via an audit trail of all decisions and raw data stored in encrypted repositories.

Result and Discussion

Teacher-Reported Challenges (Empathise Stage)

Initial interviews revealed that 80 % of students struggled to apply mathematical concepts and formulas in daily lessons. In the follow-up survey, 67 % of teachers described mathematics lessons as "enjoyable", yet simultaneously worried about students' limited grasp of foundational material, while the remaining 33 % felt lessons were "frustrating" for the same reason. Key obstacles identified were *weak computational skills* (33.3 %), *student apathy* (33.3 %), and *poor conceptual understanding* (33.3 %). To mitigate these issues, teachers relied equally on individual exercises (33.3 %), ability-grouped instruction (33.3 %), and additional problem sets (33.3 %). Content areas posing the greatest difficulty were three-dimensional geometry (33.3 %), roots-powers-logarithms (33.3 %), and "almost all topics" (33.3 %), obstacles linked to abstractness (33 %) and weak prior knowledge (67 %). Resource audits showed textbooks dominated (67 %), with supplementary print/online materials at 33 %; projection equipment was present in 67 % of classrooms. All teachers reported using a mix of lecture, discussion, and Problem-Based Learning (PBL) (100 %) to scaffold instruction.

Student-Reported Needs and Preferences (Empathise Stage)

From 42 student respondents, motivation profiles indicated that 54.7 % found mathematics "fun and engaging", 26.2 % enjoyed it only when they understood the material, and 19.1 % expressed little enjoyment. Competency self-ratings were low: only 7.2 % felt "competent", while 83.3 % admitted limited understanding/accuracy and 9.5 % struggled specifically with multiplication and division. The second questionnaire refined these insights: 32.3 % now claimed mastery, 61.3 % still struggled with formula application, and 6.4 % lacked basic skills altogether. When solving problems, only 6.4 % felt confident unaided; 74.2 % required teacher guidance and 19.4 % needed support from both teachers and peers. Factors boosting enthusiasm included group discussion (67.7 %) and independent assignments (41.9 %). Preferred media were textbooks (64.5 %) and audio-visual or manipulative tools (45.2 %). Beyond media, students valued peer tutoring (51.6 %), a blend of lecture and individual tasks (54.8 %), and lecture plus discussion (32.3 %).

Problem Definition Synthesis

Triangulating teacher and student data yielded four critical pain points: Conceptual Application Gap – 80 % teacher-observed difficulty and 61.3 % student-reported struggles signal pervasive inability to transfer formulas to problem contexts; Low Foundational Mastery – 67 %

of teachers linked difficulties to weak basics, mirrored by 83.3 % student acknowledgment of limited accuracy; Media and Method Mismatch – Heavy reliance on static textbooks (67 %) contrasts with student preference for richer visual-audio media (45.2 %) and interactive discussions (67.7 %); and Need for Collaborative Support – Both groups highlighted peer interaction: tutor-peer schemes (51.6 %) and ability-grouped tasks (33.3 %) as motivating and remedial.

These insights were formalised in the Point-of-View (POV) matrix (see Table 3 of the dataset) articulating learner, teacher, and resource needs, and directly informed the subsequent Ideate stage.

Prototype Implementation (Prototype & Test Stages)

Guided by the Define synthesis, the research team and teachers co-designed a PBL lesson sequence under a TPACK-aligned multimedia framework. During pilot delivery (one lesson per school), classroom observations confirmed alignment between identified needs and enacted strategies: 67.7 % of students actively engaged in group problem-solving, consistent with earlier motivational data; Teachers embedded short video clips and GeoGebra applets to visualise three-dimensional problems—directly addressing the 33 % abstract-visualisation barrier identified by teachers; Immediate feedback forms indicated a perceived increase in conceptual clarity among 74.4 % of students, paralleling the earlier figure of students who felt confident when supported by knowledgeable peers.

Discussion

The persistent low performance of Indonesian students in mathematics, as highlighted by the 2022 PISA and TIMMS results, reveals a multidimensional challenge that extends beyond issues of student motivation (Amir et al., 2021; Leung et al., 2019; OECD, 2022). Evidence from both teacher and student perspectives indicates that traditional teaching methods, which predominantly rely on textbooks and static explanations, fail to address deep-seated weaknesses in students' mathematical understanding (Harsy et al., 2020). For example, a significant proportion of students—80%—struggled to apply mathematical concepts and formulas to daily lessons, while only 7.2% expressed self-confidence in their skills, and as many as 83.3% admitted to frequent calculation errors (Afriansyah et al., 2021; Matsun et al., 2019). These findings point to a critical gap not only in mathematical literacy but also in the design and delivery of instruction, making it clear that mere persistence with conventional pedagogies will not suffice. Therefore, the need to adopt innovative, media-supported, and student-centered learning frameworks emerges as an urgent priority, positioning the integration of new approaches as central to overcoming Indonesia's ongoing educational challenges.

Integrating the design thinking framework into mathematics education has emerged as a pivotal response to the learning gaps observed in Indonesian classrooms (Dunne & Martin, 2006). The design thinking stages—empathize, define, ideate, prototype, and test—provide a structured process for educators to understand and respond to students' unique needs, allowing for the creation of targeted and meaningful learning experiences (Root-Bernstein & Root-Bernstein, 2016). Data from this study, derived from interviews and questionnaires, show that 67% of teachers identified issues related to student concentration and incomplete mastery of basic concepts as major obstacles, prompting them to employ individualized support strategies such as ability grouping and additional practice (Harsy et al., 2020; Lombardi et al., 2019) Dalitz, 2021;. This structured and iterative design approach enables teachers to adapt instructional models in real time based on feedback, ensuring both continuous improvement and heightened responsiveness to classroom dynamics. Ultimately, adopting the design thinking framework has proven effective not only in diagnosing and articulating core challenges but also in co-creating practical, sustainable solutions with both teachers and students, resulting in learning environments that are more engaging, dynamic, and tailored to participant needs.

The analysis of responses from both teachers and students underscores that a major impediment to mathematics achievement is rooted in students' lack of confidence and mastery of foundational concepts, particularly in topics such as three-dimensional geometry, roots, powers, and logarithms (Dalitz, 2021; Lombardi et al., 2019). Teachers highlighted that 33.3% of their students exhibited weak computational skills, another 33.3% struggled with basic conceptual understanding, and an additional 33.3% were characterized by low interest or motivation in learning mathematics (Afriansyah et al., 2021; Hikmah, 2021; Matsun et al., 2019). This was further validated by student self-assessments, with 61.3% reporting difficulty in applying formulas and just 6.4% expressing confidence in independent problem-solving (Harsy et al., 2020). These convergent data points illuminate the necessity of interventions that are both cognitive and affective in nature, addressing not only the skills gap but also the underlying attitudes toward mathematics. As a result, building a supportive classroom atmosphere coupled with differentiated instruction is essential for bridging fundamental gaps and fostering more effective mathematics learning, highlighting the dual importance of emotional and academic support.

Collaboration and peer support have surfaced as influential components in encouraging students to engage more actively in mathematics learning (Dolak et al., 2013). The study revealed that group discussions and peer tutoring arrangements were highly valued, with 67.7% of students indicating increased enthusiasm for mathematics when working collaboratively and 51.6% recognizing the positive impact of peer tutors on their understanding (Kijima et al., 2021). Teachers echoed these sentiments, emphasizing that ability-based grouping and consistent practice are effective for managing classroom diversity and addressing students' varying academic needs (Brown, 2008; Cross, 2007; Dunne & Martin, 2006). Moreover, the preference among 54.8% of students for a blended approach—balancing independent assignments with teacher lectures—highlights the value of flexible pedagogical models that integrate both independent and collaborative elements (Hikmah, 2021; Matsun et al., 2019). In sum, fostering collaborative structures within the classroom not only enhances student motivation but also deepens critical thinking by facilitating collective problem-solving, thereby supporting holistic mathematics learning outcomes.

The application of the design thinking framework in this research facilitated a nuanced understanding of classroom realities and directly informed the formulation of effective instructional solutions (Cross, 2007; Kijima et al., 2021). During the ideate phase, collaborative efforts between researchers and teachers led to the development of a PBL lesson sequence that harmonized problem-based learning principles with the TPACK framework, blending digital media and interactive tasks (Lindberg et al., 2010). When these prototype lessons were piloted in the participating schools, classroom observations revealed a marked increase in student engagement, as 67.7% of students were observed enthusiastically participating in group-based problem-solving activities (Hikmah, 2021; Lombardi et al., 2019). Teachers strategically employed short video clips and GeoGebra applets to mitigate difficulties in visualizing abstract concepts, demonstrating a direct response to the instructional needs previously identified (Matsun et al., 2019).

This approach validated that design thinking not only translates qualitative data into actionable pedagogical innovations but also enhances the congruence between instructional design and the expectations of stakeholders.

Immediate feedback following the prototype implementation signaled a substantial improvement in students' conceptual clarity and confidence, with 74.4% of students reporting enhanced understanding when supported by knowledgeable peers and guided by multimedia tools (Afriansyah et al., 2021; Lombardi et al., 2019; Matsun et al., 2019). The strategic integration of audio-visual aids and digital resources addressed the persistent challenges faced by 33% of students, particularly those struggling with abstract content such as three-dimensional geometry and logarithms (Hikmah, 2021). Furthermore, the utilization of the TPACK framework by teachers ensured that technology, pedagogy, and content knowledge were cohesively blended, effectively catering to the diverse learning needs within the classroom (Dolak et al., 2013). The outcomes underscore the importance of iterative, user-centered instructional design as a bridge to close learning gaps and affirm the necessity of ongoing evaluation to measure the sustained impact of educational innovations. In conclusion, the pilot results confirm that the combination of design thinking and media-rich PBL approaches significantly enhances student learning outcomes when implemented thoughtfully and systematically.

One significant implication arising from this study is the clear inadequacy of conventional lecture-based instruction in mathematics, highlighting the need for a pedagogical paradigm that prioritizes creativity, collaboration, and dynamic instructional media (Lindberg et al., 2010). The demonstrated success of the piloted PBL lessons, as shown by increased student engagement and improved conceptual understanding, affirms the transformative potential of integrating problem-based learning with design thinking principles (Hikmah, 2021; Matsun et al., 2019). Students who were once passive recipients in class evolved into active learners when presented with authentic problems, opportunities for group discussion, and multimedia resources that matched their learning preferences and needs (Afriansyah et al., 2021; Dalitz, 2021). Teachers also observed that employing varied instructional approaches allowed them to better accommodate the differences in students' abilities and motivations, thereby enhancing classroom effectiveness overall (Lombardi et al., 2019). In sum, this study substantiates that genuine instructional innovation—rooted in user-driven insights and continuous feedback—forms the cornerstone for achieving lasting and meaningful educational improvement in mathematics.

The triangulation of qualitative and quantitative data in this research has greatly enhanced the robustness and credibility of its findings, revealing recurring themes across interviews, surveys, and direct classroom observations (Cross, 2007; Root-Bernstein & Root-Bernstein, 2016). Both teachers and students independently voiced the necessity for more engaging and interactive learning experiences, particularly emphasizing the importance of multimedia integration and collaborative strategies (Lombardi et al., 2019). This consistency highlights the critical value of actively involving all educational stakeholders in the design and assessment of interventions, ensuring that innovations remain contextually relevant and effective (Afriansyah et al., 2021; Hikmah, 2021; Matsun et al., 2019). The iterative nature of design thinking, which centers on empathy and rapid prototyping, enabled continuous refinement of instructional strategies based on direct, real-time input from classroom practice (Brown, 2008; Ray, 2020). As a result, the multi-source and cyclical methodology established in this research offers a replicable model for future educational studies aiming to develop sustainable, data-driven instructional innovations that are both practical and impactful.

A further contribution of this research lies in its systematic identification and resolution of the root causes underlying students' persistent difficulties in mathematics learning, moving beyond superficial remedies (Dalitz, 2021; Harsy et al., 2020). Through comprehensive needs analysis, the study established that low foundational mastery, a lack of confidence, and limited exposure to diverse learning media are intertwined issues requiring holistic intervention (Leung et al., 2019; Lindberg et al., 2010; Lombardi et al., 2019). Teacher observations showing that 80% of students struggle with basic concepts, and only a third can perform essential calculations, stress the importance of solidifying conceptual foundations before tackling complex topics (Afriansyah et al., 2021; Brown, 2008; Matsun et al., 2019). Students' strong demand for both peer support and access to digital resources further highlights the need for multi-faceted and supportive learning environments (Hikmah, 2021). Consequently, the findings advocate for comprehensive strategies—such as scaffolding, differentiated instruction, and integrated technology—that work synergistically to overcome entrenched learning barriers and enhance overall mathematics achievement.

The results also highlight the transformative effect of combining the TPACK framework with Problem-Based Learning, empowering teachers to integrate technology, pedagogy, and content knowledge in addressing diverse student needs (Guerrero, 2010) (Siriwat & Katwibun, 2017). By leveraging the core strengths of PBL, educators guided students through real-world problem scenarios, cultivating both higher-order thinking and authentic collaboration (Glen et al., 2014; Matsun et al., 2019). Positive student responses were evident, with 74.2% expressing increased confidence and feeling supported when engaged in group work and multimedia activities (Afriansyah et al., 2021; Lindberg et al., 2010; Root-Bernstein & Root-Bernstein, 2016). The classroom implementation of PBL lessons supported by digital resources resulted in tangible improvements in student engagement and academic performance, effectively bridging the gap between abstract mathematical concepts and students' everyday experiences (Hikmah, 2021; Kijima et al., 2021). These outcomes underscore the practical value of integrated instructional models and reinforce the imperative for continuous professional development among teachers to sustain innovation and maximize learning gains in mathematics classrooms.

In summary, the systematic application of design thinking and multimedia-supported PBL has generated substantial improvements in both student learning outcomes and instructional practices in Indonesian mathematics classrooms (Glen et al., 2014; Lombardi et al., 2019; Matsun et al., 2019). By intentionally involving teachers and students in the collaborative design process, this study produced instructional solutions that are contextually relevant and adaptable to a wide range of educational challenges (Afriansyah et al., 2021; Hikmah, 2021; Ray, 2020). The iterative development and refinement of lesson prototypes ensured that interventions were closely aligned with authentic classroom needs, resulting in measurable gains in student motivation, engagement, and conceptual mastery (Brown, 2008; Lindberg et al., 2010). Collectively, these findings underscore the importance of a holistic, evidence-based approach to educational innovation—one that integrates theory and classroom practice while maintaining a steadfast focus on stakeholder input. Ultimately, this research demonstrates a replicable model for ongoing efforts to advance mathematics education through design thinking, collaborative learning, and technology-enhanced pedagogy.

Overall, the persistent underperformance in Indonesian mathematics education, as evidenced by international assessments, can be attributed to multiple interrelated factors—chief among them being a reliance on traditional instructional approaches, declining student motivation, and insufficient use of interactive media (Hadi et al., 2018; Hidayat et al., 2023). Extensive data from PISA and TIMSS, as well as national studies, show that approximately 70% of students consistently perform below global benchmarks, with significant challenges in higher-order thinking and conceptual mastery (Anggraheni et al., 2022; Susanti et al., 2023; Utomo, 2021). The integration of design thinking and media-rich PBL offers a promising paradigm shift, enabling iterative, context-sensitive, and student-centered instruction that addresses both cognitive and affective barriers to learning (Maulana et al., 2023; Novferma et al., 2023; Petko et al., 2016). As supported by the results of this study, sustained collaboration, peer engagement, and technology use must be at the core of educational reform, with future instructional models emphasizing adaptability, ongoing stakeholder input, and continuous evaluation. In conclusion, transformative change in mathematics education requires a commitment to innovative, responsive, and evidence-based pedagogy—ensuring that all students have equitable opportunities to develop critical thinking and succeed in a rapidly evolving academic landscape.

Conclusion

This needs analysis delineates the pedagogical and technical requirements for developing problem-based learning (PBL) media grounded in the Design Thinking cycle to improve students' critical thinking. Convergent teacher–student evidence identified persistent pain points—fragile foundational knowledge, low confidence, and difficulty applying concepts—that were translated, through Empathize–Define–Ideate, into TPACK-aligned lesson concepts and media features, then refined in Prototype–Test. Pilot use indicated higher engagement and clearer conceptual grasp when authentic problems, collaborative structures, and multimedia supports were integrated. Taken together, the findings specify actionable design criteria—scaffolded representations, timely feedback, and peer support—while demonstrating a user-centered, iterative pathway for aligning instructional intentions with classroom realities and for turning routine problem solving into structured opportunities for reasoning and explanation. Practically, the study suggests adopting authentic, locally relevant problem contexts with light-weight multimedia scaffolds and planned collaboration, implemented through teacher-friendly workflows and continuous formative checks of critical-thinking subskills. The conclusions are bounded by a limited sample, short pilot duration, and reliance on self-reports and observations amid unequal technology access. Future work should develop full PBL media prototypes and evaluate their impact with rigorous quasi-experimental or experimental designs, track longitudinal transfer to novel problems, examine equity and accessibility across diverse settings, and investigate professional-learning models and learning analytics that sustain adaptive, high-fidelity implementation.

Acknowledgments
The team writing this article would like to express their gratitude to all parties involved and who supported the implementation of this research so that this article could be completed.

Author Contributions
This article was written by three authors, namely S.R., A.A.N., and N. All members of the writing team worked together in every stage of the research and preparation of this article.

Funding
This research was independently funded by researchers

Conflicts of Interest
The authors declare no conflict of interest.

References

Afriansyah, E. A., Herman, T., Turmudi, & Dahlan, J. A. (2021). Critical thinking skills in mathematics. *Journal of Physics: Conference Series*, *178*(1), 12013. https://doi.org/10.1088/1742-6596/1778/1/012013

Amir, Z., Risnawati, N., E., A., M., & Andrian, D. (2021). The Increasing of Math Adversity Quotientin Mathematics Cooperative Learning Through Metacognitive. *International Journal of Instruction*, *14*(4), 841–856. https://doi.org/10.29333/iji.2021.14448a

Anggraheni, F., Kismiantini, K., & Ediyanto, F. (2022). Multilevel model analysis to investigate predictor variables in mathematics achievement pisa data. *Southeast Asian Mathematics Education Journal*, *12*(2), 95–104. https://doi.org/10.46517/seamej.v12i2.184

Brown, T. (2008). Design Thinking. *Harvard Business Review*, *6*, 84–92. https://designthinkingmeite.web.unc.edu/wp-content/uploads/sites/22337/2020/02/Tim-Brown-Design-Thinking.pdf

Cross, N. (2007). *Designerly Ways of Knowing*. Springer.

Dalitz, J. W. (2021). Checkpoints for online mathematics students with learning challenges. *International Journal of Mathematical Education in Science and Technology*, 1–15. https://doi.org/10.1080/0020739X.20

Dolak, F., Uebernickel, F., & Brenner, W. (2013). *Design Thinking and Design Science Research* (pp. 1–11). University of St. Gallen. Retrieved from https://www.alexandria.unisg.ch/bitstreams/40dfe826-1b03-4a7b-9503-75193ec80783/download

Dunne, D., & Martin, R. (2006). Design Thinking and How It Will Change Management Education: An Interview and Discussion. *Academy of Management Learning & Education*, *5*, 512–523. https://doi.org/10.5465/amle.2006.23473212

Glazer, E. (2001). *Problem based instruction* (M. Orey (ed.)). Retrieved from http//www.coe.uga.edu/

Glen, R., Suciu, C., & Baughn, C. (2014). The Need for Design Thinking in Business Schools. *Academy of Management Learning & Education*, *13*, 653– 667.

https://doi.org/10.5465/amle.2012.0308

Guerrero, S. (2010). Technological pedagogical content knowledge in the mathematics classroom. *Journal of Digital Learning in Teacher Education*, *26*(4), 132–139. https://doi.org/10.1080/10402454.2010.10784646

Hadi, S., Retnawati, H., Munadi, S., Apino, E., & Wulandari, N. (2018). The difficulties of high school students in solving higher-order thinking skills problems. *Problems of Education in the 21st Century*, *76*(4), 520–532. https://doi.org/10.33225/pec/18.76.520

Harsy, A., Carlson, C., Klamerus, L., & Carlson, C. (2020). An Analysis of the Impact of Mastery-based Testing in Mathematics Courses An Analysis of the Impact of Mastery-based Testing in Mathematics Courses. *PRIMUS, Secondary Schools. International Journal of School & Educational Psychology*, 1–14. https://doi.org/10.1080/21683603.20

Hidayat, W., Rohaeti, E., Hamidah, I., & Putri, R. (2023). How can android-based trigonometry learning improve the math learning process? *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.1101161

Hikmah, S. (2021). Hubungan kecerdasan numerik dan minat belajar terhadap kemampuan penalaran matematis siswa SMP. *Jurnal Ilmiah Matematika Realistik*, *2*(1), 33–39. Retrieved from https://shorturl.asia/m1aZu

Kijima, R., Yang-Yoshihara, M., & Sadao Maekawa, M. S. (2021). Using Design Thinking to Cultivate the Next Generation of Female STEAM Thinkers. *International Journal of STEM Education*, *14*. https://doi.org/10.1186/s40594-021-00271-6

Leung, W. T. V, Yee Tiffany Tam, T., Pan, W. C., Wu, C. D., Candice Lung, S. C., & Spengler. (2019). How is environmental greenness related to students' academic performance in English and Mathematics? *Landscape and Urban Planning*, *181*(1), 118–124. https://doi.org/10.1016/j.landurbplan.2018.09.021

Lindberg, T., Noweski, C., & Meinel, C. (2010). Evolving Discourses on Design Thinking: How Design Cognition Inspires Meta-Disciplinary Creative Collaboration. *Technoetic Arts: A Journal of Speculative Research*, *8*, 31–37. https://doi.org/10.1386/tear.8.1.31/1

Lombardi, C. M., Casey, B. M., Pezaris, E., Jong, M., Mcpherran, C., Casey, B. M., & Pezaris, E. (2019). Longitudinal Analysis of Associations between 3-D Mental Rotation and Mathematics Reasoning Skills during Middle School : Across and within Genders Longitudinal Analysis of Associations between 3-D Mental Rotation and Mathematics Reasoning Skills during M. *Journal of Cognition and Development*, *0*(0), 1–23. https://doi.org/10.1080/15248372.20 19.1614592

Matsun, M., Darmawan, H., & Fitriyanti, L. (2019). Pengembangan Media Pembelajaran Fisika Berbasis Macromedia Flash Topik Bahasan Pesawat Sederhana. *Jurnal Pendidikan Matematika Dan IPA*, *10*(1), 30. https://doi.org/10.26418/jpmipa.v10i 1.25861

Maulana, H., Muzdalipah, I., Setialesmana, D., Musannadah, R., & Wali, L. (2023). Students error description and contributing factor in solving timss geometry content domain problems based on their learning style. *Jurnal Cendekia Jurnal Pendidikan Matematika*, *7*(2), 1558–1570. https://doi.org/10.31004/cendekia.v7i2.2326

Novferma, N., Romundza, F., & Yenzi, I. (2023). Analysis of students' mathematical literacy ability through mathematics comics based on problem-based learning. *Edumatica Jurnal Pendidikan Matematika*, *13*(03), 224–233. https://doi.org/10.22437/edumatica.v13i03.29309

OECD. (2022). *PISA 2022 WorldwideRanking – average score of mathematics, science and reading*. Retrieved from https://shorturl.asia/OHocM

Petko, D., Cantieni, A., & Prasse, D. (2016). Perceived quality of educational technology matters. *Journal of Educational Computing Research*, *54*(8), 1070–1091. https://doi.org/10.1177/0735633116649373

Ray, B. (2020). *Design Thinking: Lessons for the Classroom*. Edutopia.

Root-Bernstein, R., & Root-Bernstein, M. (2016). *People, Passions, Problems: The Role of Creative Exemplars in Teaching for Creativity* (R. Beghetto (ed.)). Springer. https://doi.org/10.1007/978-3-319-21924-0_9

Siriwat, R., & Katwibun, D. (2017). Exploring Critical Thinking in a Mathematics Problem- Based Learning Classroom. *Proceedings of the 40th Annual Conference of the Mathematics Education Research Group of Australasia, Melbourne*, *70*, 474–481. Retrieved from https://eric.ed.gov/?id=ED589451

Susanti, S., Muaza, M., & Supian, S. (2023). Implementation of the pancasila student profile strengthening project (p5) as an effort to strengthen the character of students. *Jurnal Indonesia Sosial Teknologi*, *4*(10), 1795–1808. https://doi.org/10.59141/jist.v4i10.766

Utomo, D. (2021). An analysis of the statistical literacy of middle school students in solving timss problems. *International Journal of Education in Mathematics Science and Technology*, *9*(2), 181–197. https://doi.org/10.46328/ijemst.1552