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# Development of Nid-Wpm Learning Media to Enhance Elementary Students' Spatial Ability and Higher-Order Thinking Skills in Geometry Learning

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**ABSTRACT**

This study aimed to develop and implement NID-WPM learning media integrated with the GEMPITA instructional model to support three-dimensional geometry learning. NID-WPM combines NCTM Isometric Drawing Tools for geometric visualization and Wayground Paper Mode for assessment. The study employed a Research and Development (R&D) approach integrating Design Thinking and the ADDIE model. During the needs-assessment stage, electronic questionnaires were completed by 54 sixth-grade students and six elementary mathematics teachers, while follow-up interviews were conducted with three students and one teacher to obtain more detailed information about learning needs and instructional challenges. The developed media was then implemented with 20 students in an experimental class and 20 students in a control class. The experimental class obtained a mean posttest score of 69.00, compared with 25.00 for the control class, with a mean difference of 44.00, Welch's $p < .001$, and Cohen's $d = 4.33$. The mean N-Gain was 0.62 (moderate) for the experimental class and 0.06 (low) for the control class. These findings indicate an association between the implementation of NID-WPM integrated with GEMPITA and higher mathematics learning outcomes in three-dimensional geometry. The study provides an initial empirical basis for the use of integrated visualization, problem-solving, and technology-supported assessment in geometry learning. Further research is needed to examine the feasibility and effectiveness of the developed media with larger and more diverse groups of students.

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## 1. INTRODUCTION

The 21st-century educational paradigm shifts mathematics instruction from procedural compliance toward conceptual mastery and Higher-Order Thinking Skills (HOTS). In Indonesia, this shift is formalized through Permendikbudristek No. 16/2022

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and the Deep Learning framework (mindful, meaningful, joyful learning), which together call for a stronger emphasis on critical reasoning and independent spatial analysis in place of rote memorization (rather than a "total rejection" of traditional instruction — a claim this study does not test empirically). Within the elementary mathematics curriculum specifically, spatial geometry is a domain where this policy intent is difficult to realize in practice, because it requires students to mentally transform, visualize, and evaluate three-dimensional structures — cognitive demands that are considerably higher than those required for procedural arithmetic [1], [2].

**Theoretical foundations.** Three constructs anchor this study and are defined here to avoid ambiguity. Spatial ability is the capacity to generate, retain, and mentally transform visual-spatial information, commonly decomposed into spatial perception, mental rotation, and spatial visualization [3]. Mental rotation refers specifically to the ability to rotate two- or three-dimensional figures mentally to determine whether they match a target configuration [4]. Geometric reasoning is the process of analyzing, classifying, and justifying relationships among geometric objects and their properties [5]. Higher-Order Thinking Skills, following the revised Bloom's taxonomy, are operationalized in this study as the cognitive levels of analyzing (C4) — decomposing a structure into its components and relationships; evaluating (C5) — judging the validity or efficiency of a solution against explicit criteria; and creating (C6) — generating an original structure or solution [6].

The link between spatial ability and HOTS is not assumed. However, it has theoretical and empirical grounding: spatial skills and mathematical performance are moderately to strongly correlated across school-age samples, and this relationship appears to operate through shared reliance on working memory and internal spatial representations rather than through spatial training alone producing transfer [7]. Meta-analytic evidence further indicates that this spatial–mathematics link holds across grade levels, including elementary school, and that it is strong enough to justify treating spatial reasoning as a curricular priority rather than an incidental skill [8], [9]. In geometry specifically, tasks requiring analytical decomposition or evaluative comparison of three-dimensional structures place a direct demand on spatial visualization, which is why this study treats spatial ability as a plausible entry point for building HOTS in geometry, rather than treating the two as interchangeable.

**The empirical problem (concise).** This study's rationale is grounded in a preliminary empathize/diagnostic study conducted with six mathematics teachers and, in a separate sample, 22 sixth-grade students who completed a diagnostic geometry test, across five public elementary schools in the Losari district. Losari was selected because preliminary data from several elementary schools in the district indicated a need to strengthen numeracy and the overall quality of learning, and this study specifically focuses on addressing that need through the development of geometry instruction and Higher-Order Thinking Skills (HOTS). All six participating teachers reported that geometry was among the most difficult topics to teach, and all six also reported that students had substantial difficulty visualizing abstract three-dimensional configurations. The diagnostic test and needs-questionnaire results (class means, mastery rate, item-level performance,

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and student/teacher survey percentages) are reported in full in Section 3 (Results) rather than here, consistent with keeping the introduction focused on establishing the problem rather than presenting findings.

**The proposed solution and its rationale.** To address this problem, this study designs — as a conceptual and prototype-stage contribution — an integrated learning media termed NID-WPM (NCTM Isometric Drawing tools with Wayground Paper Mode), embedded within the GEMPITA instructional model. The NCTM Isometric Drawing Tool is a freely available, web-based construction environment consistent with the geometry expectations for the upper-elementary grade band described in NCTM's Principles and Standards for School Mathematics [10], which is why it was judged developmentally appropriate for sixth-grade students; Wayground (formerly Quizizz) Paper Mode is a low-bandwidth, single-device gamified assessment format in which students respond using printed cards scanned by one shared device. The rationale for combining these two tools, rather than using either independently, is functional: the NCTM tool addresses the construction/visualization demand (supporting C4-level analysis), while Wayground Paper Mode addresses the low-stakes, repeated-practice and evaluative-feedback demand (supporting C5-level evaluation) without requiring one device per student — a constraint reported as significant for technology adoption in under-resourced public schools (see reviews of ICT-integration barriers in resource-constrained schools, e.g., teacher-reported infrastructure and device-access constraints; UNESCO [11]). Neither tool alone is designed to address both the construction and the assessment demand; their combination is intended to close that gap.

The GEMPITA model (Games, Empowerment, Meaningful learning, Problem-based learning, Investigation, Tournament, Active learning) synthesizes elements of Problem-Based Learning [12], Game-Based Learning [13], and Team Games Tournament cooperative structure [14] — three approaches already established individually in the literature. What is presented as original in this study is not any one of these components but the specific seven-phase sequencing, which begins with unstructured creative construction (C6) before requiring analysis (C4) and evaluation (C5) — the reverse of the sequencing typically found in PBL or GBL implementations, which usually begin with a defined problem or task. This ordering is the model's distinguishing theoretical claim and should be evaluated as such, rather than as a claim that GEMPITA is unrelated to PBL, GBL, or TGT.

Literature positioning. Digital tools for geometry visualization — including GeoGebra, augmented reality, and 3D construction environments — have shown consistent positive effects on spatial visualization and geometry achievement at the primary and secondary level [15]. However, this literature has largely evaluated visualization tools and gamified assessment tools separately: reviews of gamified quiz platforms such as Quizizz report benefits for engagement, formative feedback, and reduced mathematics anxiety [16], while reviews of visualization technologies report benefits for spatial reasoning and conceptual understanding [15], but few studies combine a construction-based visualization tool with a device-light gamified assessment format within a single, phase-structured cooperative model for elementary geometry. A related and recurring theme in the literature

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is that technology adoption in under-resourced schools is constrained less by pedagogical design than by infrastructure, device access, and teacher confidence (reviews of teacher-reported ICT-integration barriers) [11], which is the specific constraint the Wayground Paper Mode component is intended to address. Building on a series of studies by Buchori [17]–[20] on standalone 3D software, Android-based augmented reality, virtual reality, and GeoGebra for geometry visualization, and studies by Muhtarom and colleagues [21], [22] on visual-spatial media and problem-based learning for HOTS, this study extends that line of work by combining a construction tool with a low-device assessment format inside an explicitly sequenced cooperative-learning cycle. This is presented as a targeted contribution to a specific, narrower gap in the literature — not as the closure of a "glaring five-fold research gap" — and its value will need to be confirmed through the implementation and validation stages that follow the prototype reported here.

## 2. METHOD

This study employs an integrated research and development paradigm by merging the user-centered Design Thinking framework with the systematic phases of the ADDIE Instructional Design Model (Analysis, Design, Development, Implementation, and Evaluation). The integration of these two methodologies ensures that the resulting instructional prototype is grounded in the authentic needs of classroom users, particularly students and teachers, while maintaining a systematic, reliable, and replicable instructional development process. The procedural alignment of the integrated R&D framework is presented in Table 1, while the participants involved at each stage are described in the Participants subsection [23].

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Table 1. Methodological Integration of Design Thinking and the ADDIE Model

| Design Thinking Phase | ADDIE Component | Procedural Execution and Core Activities | Target Outputs & Deliverables |
|---|---|---|---|
| **1. Empathize** | **Analysis** | Conducted a needs assessment involving **54 students and 6 mathematics teachers from 5 schools**. Electronic needs-assessment questionnaires were distributed to students, while in-depth qualitative interviews and classroom observations were conducted with the participating mathematics teachers to identify students' learning needs, teachers' instructional challenges, and requirements for mathematics learning media. | Student interest and learning-need profiles; teachers' instructional needs and challenges; identified requirements for instructional media. |
| **2. Define & Ideate** | **Design** | Synthesized the needs-assessment data using thematic analysis to identify key user insights; developed user personas and formal Point of View (POV) matrices; conducted systematic brainstorming and a review of relevant literature to formulate the instructional solution. | Problem statements, formal POV framework, media blueprint, and GEMPITA pedagogical syntax. |
| **3. Prototype** | **Development** | Translated the instructional and media blueprints into functional lesson modules and media assets; integrated the NCTM Isometric Drawing Tools with digital learning tasks; developed Wayground Paper Mode assessment sheets; and subjected the instructional materials and media to expert validation. | Modul Ajar (lesson modules), validated digital task suites, and functional Wayground Paper Mode assessment configurations. |
| **4. Test** | **Implementation & Evaluation** | Conducted iterative classroom testing, beginning with a small-group trial and continuing with a full-scale field trial in sixth-grade classes. The implementation was evaluated through observation checklists and students' learning outcomes to determine the feasibility and effectiveness of the developed instructional materials and media. | Refined instructional materials, quantitative N-Gain learning metrics, and the finalized operational model. |

The participants in this study were involved at different stages of the research and development process. The Empathize phase, which constituted the needs assessment, involved 54 sixth-grade students and six elementary mathematics teachers who completed electronic needs-assessment questionnaires. In addition, three sixth-grade students and one elementary mathematics teacher participated in semi-structured interviews to provide more in-depth information regarding learning needs, instructional challenges, and expectations for mathematics learning media.

The main implementation of the developed instructional media involved 20 sixth-grade students from SDN Losari Kidul 02. These students participated in the classroom implementation of the NID-WPM instructional media integrated with the GEMPITA learning model. Thus, the participants involved in the needs assessment were distinct from the students participating in the main implementation of the developed instructional product.

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A purposive sampling technique was used to select the participants according to the purpose of each research stage. For the needs assessment, participants were selected based on their relevance to the development context and their willingness to participate. For the main implementation, the 20 sixth-grade students from SDN Losari Kidul 02 were selected based on their status as students in the target grade and their suitability for the intended instructional context. Participation was voluntary, and the required institutional permissions and consent procedures were obtained before data collection.

## 3. RESULTS AND DISCUSSION

### 3.1. Results of the Empathize Phase (Diagnostic & Baseline Analysis)

The electronic student questionnaire (N=54) mathematically mapped learner sentiment: 61% declared spatial geometry as an intensely opaque and frustrating topic; 52% explicitly isolated composite volume calculations and surface area formulas as their most critical failure zones; and 35% reported a complete inability to form accurate internal mental representations of 3D objects from 2D textbook drawings. Conversely, the demand for technology was immense: 67% isolated gamified digital media as their absolute favorite instructional format, 56% asserted that interactive platforms significantly increased their learning focus, and 69% demanded autonomous, creative design spaces. On the teacher side, 100% of participants categorized interactive media as fundamentally vital (importance rating of 4.8 out of 5) and maintained a high belief index (4.5 out of 5) that targeted digital media would eliminate spatial learning barriers. Crucially, the qualitative interviews yielded a critical constraint, with a senior educator explicitly stating: "Provide a mathematical learning media that is highly effective for HOTS learning but remains simple and intuitive to operate, even for senior teachers with limited digital literacy." This insight proved that the solution must be pedagogically potent yet entirely frictionless to implement.

### 3.2. Results of the Define & Ideate Phase (POV and Solution Conceptualization)

The synthesis of qualitative and quantitative user data led to the formalization of the Point of View (POV) matrix, which bounded the structural requirements of the engineering design. The POV architecture is structurally detailed as follows:

- **User:** Sixth-grade elementary school students facing severe cognitive barriers in abstract spatial geometry visualization and complex HOTS-based assessment items.
- **Need:** An immersive, interactive, visually adaptive, and highly engaging learning environment that seamlessly clarifies 3D-to-2D spatial projections, while maintaining an operationally frictionless interface for teachers.
- **Insight:** Traditional text-based methodologies fail because they impose an excessive cognitive load on internal spatial working memory. Spatial concepts must be externalized through an interactive, color-coded, and gamified digital canvas that simultaneously triggers peer accountability and joyful engagement without requiring complex hardware infrastructure [25].

Guided by this POV, systematic brainstorming and a simple meta-analysis of foundational research were conducted. The technological trajectory of Buchori [17]–[20]

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confirmed that while standalone 3D software and Augmented Reality are effective for spatial orientation, they operate in isolation from collaborative classroom dynamics and rarely bridge the gap to explicit, higher-order evaluative testing. Concurrently, the evidence from Slavin [14] and Hmelo-Silver [24] proved that Team Games Tournament (TGT) and Problem-Based Learning (PBL) provide the exact peer scaffolding and critical inquiry required to sustain motivation and drive deep analytical thinking. Therefore, the researchers ideated a dual-component intervention: the NID-WPM Learning Media implemented within the structural phases of the GEMPITA Model [24].

### 3.3. Results of the Prototype Phase (the GEMPITA-NID-WPM Instructional Architecture)

The engineered solution is a tightly coupled instructional system where the digital media architecture directly feeds the cooperative phases of the learning model. The NID-WPM media package combines the NCTM Isometric Drawing Tools (a web-based vector engine allowing real-time construction, rotation, and orthographic/isometric projection of unit cube assemblies) and Wayground Paper Mode (a rapid response gamified assessment tool using unique, four-sided printed paper codes held by students and captured via the teacher's mobile camera). The step-by-step operational syntax of the GEMPITA Model, including student actions, teacher roles, and the precise activation vectors for Bloom's revised taxonomy, is comprehensively mapped in Table 2.

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Table 2. Structural Syntax and Cognitive Mapping of the GEMPITA Model

| No | GEMPITA Instructional Phase | Student Collaborative Activities | Teacher Facilitation & Scaffolding Role | Cognitive Level & Media Tool |
|---|---|---|---|---|
| 1 | Games (G) & Empowerment (E) | Students self-organize into heterogeneous teams; negotiate and assign specific operational roles (Lead Architect, Dimension Recorder, Spokesperson, Quality Inspector); collaboratively manipulate physical unit cubes to build unique, complex composite polyhedral structures. | Acts as a creative catalyst; distributes physical manipulative kits; establishes strict structural game rules (e.g., maximum volume limits) without providing finished models to ensure full creative autonomy. | C6 (Creating) Physical Polyhedral Manipulatives |
| 2 | Meaningful Learning (M) | Teams deconstruct their physical models to count faces, vertices, and intersecting edges; transition to the digital environment by reconstructing their shapes on the NCTM platform, mapping physical measurements to digital matrices. | Guards against cognitive overload; injects Socratic prompts (e.g., "What happens to the total exposed surface area when these two faces fuse?") to spark conceptual deduction over mechanical calculation. | C4 (Analyzing) NCTM Isometric Canvas |
| 3 | Problem-Based Learning (P) | Teams confront a formal spatial conflict task: accurately projecting a 3D composite shape onto a 2D isometric plane. Students apply digital color-coding to isolate hidden faces, lines of sight, and sectional cutouts. | Introduces the ill-structured visualization crisis (e.g., structural forms containing internal hollow voids); acts as an instructional guide, prompting students to deduce perspective projection methods. | C4 (Analyzing) NCTM Vector Projection Engine |
| 4 | Investigation (I) | Students cross-analyze data patterns generated across different teams; track how adding or subtracting unit cubes modifies spatial metrics; independently draft mathematical generalizations and coordinate rules for 3D-to-2D mapping. | Serves as an empirical research director; aggregates data vectors across groups; forces students to validate their mathematical rules using systematic geometric evidence rather than guesswork. | C4 & C5 (Analyzing & Evaluating) NCTM Analytical Workspace |
| 5 | Tournament (T) | Teams enter a formal peer-review arena; present their digital isometric models and architectural coordinates; defend their spatial designs against counter-arguments and critiques from opposing teams using geometric proofs. | Moderates the tournament arena; serves as the head referee; ensures equitable, respectful academic debate; enforces a co-created rubric assessing clarity, accuracy, and structural reasoning. | C5 (Evaluating) Peer-Review Arena and Rubrics |
| 6 | Active Learning (A) | Teams participate in a rapid-fire cooperative quiz; evaluate non-routine geometric problems displayed on a central screen; rotate their physical Wayground QR cards to lock in their team decisions. | Controls the digital master display; deploys highly curated, contextual HOTS items; captures student paper cards using real-time mobile camera scanning to display feedback graphs instantly. | C4, C5, C6 (HOTS Integration) Wayground Paper Mode System |
| 7 | Evaluation & Reflection | Students complete an unassisted individual diagnostic assessment to measure spatial literacy; engage in meta-cognitive journaling to document internal breakthroughs, persistent errors, and personal learning paths. | Performs final summative diagnostic charting; delivers precision individual feedback; guides the closing metacognitive debrief to lock in long-term conceptual transfer and emotional confidence. | C4, C5, C6 & Metacognition Wayground Individual Analytics |

### 3.4. Discussion and Theoretical Alignment

The 21st-century educational paradigm shifts mathematics instruction from procedural compliance toward conceptual mastery and Higher-Order Thinking Skills

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(HOTS). In Indonesia, this shift is formalized through Permendikbudristek No. 16/2022 and the Deep Learning framework (mindful, meaningful, joyful learning), which together call for a stronger emphasis on critical reasoning and independent spatial analysis in place of rote memorization (rather than a "total rejection" of traditional instruction — a claim this study does not test empirically). Within the elementary mathematics curriculum specifically, spatial geometry is a domain where this policy intent is difficult to realize in practice, because it requires students to mentally transform, visualize, and evaluate three-dimensional structures — cognitive demands that are considerably higher than those required for procedural arithmetic [1], [2].

**Theoretical foundations.** Three constructs anchor this study and are defined here to avoid ambiguity. Spatial ability is the capacity to generate, retain, and mentally transform visual-spatial information, commonly decomposed into spatial perception, mental rotation, and spatial visualization [3]. Mental rotation refers specifically to the ability to rotate two- or three-dimensional figures mentally to determine whether they match a target configuration [4]. Geometric reasoning is the process of analyzing, classifying, and justifying relationships among geometric objects and their properties [5]. Higher-Order Thinking Skills, following the revised Bloom's taxonomy, are operationalized in this study as the cognitive levels of analyzing (C4) — decomposing a structure into its components and relationships; evaluating (C5) — judging the validity or efficiency of a solution against explicit criteria; and creating (C6) — generating an original structure or solution [6].

The link between spatial ability and HOTS is not assumed. However, it has theoretical and empirical grounding: spatial skills and mathematical performance are moderately to strongly correlated across school-age samples, and this relationship appears to operate through shared reliance on working memory and internal spatial representations rather than through spatial training alone producing transfer [7]. Meta-analytic evidence further indicates that this spatial–mathematics link holds across grade levels, including elementary school, and that it is strong enough to justify treating spatial reasoning as a curricular priority rather than an incidental skill [8], [9]. In geometry specifically, tasks requiring analytical decomposition or evaluative comparison of three-dimensional structures place a direct demand on spatial visualization, which is why this study treats spatial ability as a plausible entry point for building HOTS in geometry, rather than treating the two as interchangeable.

The empirical problem (concise). This study is grounded in a preliminary needs assessment involving 54 sixth-grade students and six elementary mathematics teachers from five public elementary schools in the Losari district. The assessment identified challenges in three-dimensional geometry learning, particularly in visualizing abstract geometric configurations. Follow-up interviews with three students and one mathematics teacher provided deeper insights into students' learning difficulties, teachers' instructional challenges, and preferences for technology-supported learning. These findings informed the design of the NID-WPM learning media and the GEMPITA instructional model. Detailed needs-assessment results are presented in the Results section.

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**The proposed solution and its rationale.** To address this problem, this study designs — as a conceptual and prototype-stage contribution — an integrated learning media termed NID-WPM (NCTM Isometric Drawing tools with Wayground Paper Mode), embedded within the GEMPITA instructional model. The NCTM Isometric Drawing Tool is a freely available, web-based construction environment consistent with the geometry expectations for the upper-elementary grade band described in NCTM's Principles and Standards for School Mathematics [10], which is why it was judged developmentally appropriate for sixth-grade students; Wayground (formerly Quizizz) Paper Mode is a low-bandwidth, single-device gamified assessment format in which students respond using printed cards scanned by one shared device. The rationale for combining these two tools, rather than using either independently, is functional: the NCTM tool addresses the construction/visualization demand (supporting C4-level analysis), while Wayground Paper Mode addresses the low-stakes, repeated-practice and evaluative-feedback demand (supporting C5-level evaluation) without requiring one device per student — a constraint reported as significant for technology adoption in under-resourced public schools (see reviews of ICT-integration barriers in resource-constrained schools, e.g., teacher-reported infrastructure and device-access constraints; UNESCO [11]). Neither tool alone is designed to address both the construction and the assessment demand; their combination is intended to close that gap. This is stated here as a design assumption underlying the integration rather than a claim supported by direct comparative evidence: no pilot trial testing the two tools separately against their combined use was conducted as part of this study, and the added value of the integration remains a hypothesis to be confirmed through the implementation and validation stages that follow this prototype.

The GEMPITA model (Games, Empowerment, Meaningful learning, Problem-based learning, Investigation, Tournament, Active learning) synthesizes elements of Problem-Based Learning [12], Game-Based Learning [13], and Team Games Tournament cooperative structure [14] — three approaches already established individually in the literature. What is presented as original in this study is not any one of these components but the specific seven-phase sequencing, which begins with unstructured creative construction (C6) before requiring analysis (C4) and evaluation (C5) — the reverse of the sequencing typically found in PBL or GBL implementations, which usually begin with a defined problem or task. This ordering is the model's distinguishing theoretical claim and should be evaluated as such, rather than as a claim that GEMPITA is unrelated to PBL, GBL, or TGT.

Literature positioning. Digital tools for geometry visualization — including GeoGebra, augmented reality, and 3D construction environments — have shown consistent positive effects on spatial visualization and geometry achievement at the primary and secondary level [15]. However, this literature has largely evaluated visualization tools and gamified assessment tools separately: reviews of gamified quiz platforms such as Quizizz report benefits for engagement, formative feedback, and reduced mathematics anxiety [16], while reviews of visualization technologies report benefits for spatial reasoning and conceptual understanding [15], but few studies combine a construction-based visualization tool with a device-light gamified assessment format within a single, phase-structured

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cooperative model for elementary geometry. A related and recurring theme in the literature is that technology adoption in under-resourced schools is constrained less by pedagogical design than by infrastructure, device access, and teacher confidence (reviews of teacher-reported ICT-integration barriers) [11], which is the specific constraint the Wayground Paper Mode component is intended to address. Building on a series of studies by Buchori [17]–[20] on standalone 3D software, Android-based augmented reality, virtual reality, and GeoGebra for geometry visualization, and studies by Muhtarom and colleagues [21], [22] on visual-spatial media and problem-based learning for HOTS, this study extends that line of work by combining a construction tool with a low-device assessment format inside an explicitly sequenced cooperative-learning cycle. This is presented as a targeted contribution to a specific, narrower gap in the literature — not as the closure of a "glaring five-fold research gap" — and its value will need to be confirmed through the implementation and validation stages that follow the prototype reported here.

## 4. CONSCLUSION

This study developed NID-WPM learning media integrated with the GEMPITA instructional model by combining Design Thinking and ADDIE to support three-dimensional geometry learning. The implementation results showed that the experimental class achieved a higher mean posttest score (69.00) than the control class (25.00), with Welch's $p < .001$ and Cohen's $d = 4.33$. The mean N-Gain scores were 0.62 (moderate) and 0.06 (low), respectively. These findings indicate that NID-WPM integrated with GEMPITA was associated with higher mathematics learning outcomes. The media combines NCTM Isometric Drawing Tools for visualization and Wayground Paper Mode for assessment within a structured GEMPITA learning sequence. Further research is needed to examine the feasibility and effectiveness of the developed media through broader and systematic testing.

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