Salud, Ciencia y Tecnología. 2025; 5:2137
doi: 10.56294/saludcyt20252137

AG EDITOR

ORIGINAL

Enhancing Students' Reasoning Skills with GeoGebra-based Digital Worksheets

Mejorando las habilidades de razonamiento de los estudiantes con hojas de trabajo digitales basadas en GeoGebra

Lathiful Anwar[1], Cholis Sa'dijah[1], Yuhana Faradila Muzam Roudloh[1], Yerizon[2], Maiyastri[3]

[1]Universitas Negeri Malang, Department of Mathematics. Malang, Indonesia.
[2]Universitas Negeri Padang, Department of Mathematics. Padang, Indonesia.
[3]Andalas University, Department of Mathematics. Padang, Indonesia.

Cite as: Anwar L, Sa'dijah C, Muzam Roudloh YF, Yerizon Y, Maiyastri M. Enhancing Students' Reasoning Skills with GeoGebra-based Digital Worksheets. Salud, Ciencia y Tecnología. 2025; 5:2137. https://doi.org/10.56294/saludcyt20252137

Submitted: 26-04-2025 **Revised:** 12-07-2025 **Accepted:** 13-09-2025 **Published:** 14-09-2025

Editor: Prof. Dr. William Castillo-González

Corresponding Author: Lathiful Anwar

ABSTRACT

Introduction: cultivating robust mathematical reasoning is critical for secondary learners, underpinning skills in argumentation, justification, and problem-solving. Despite its importance, many students encounter persistent difficulties, exacerbated by a scarcity of interactive resources and insufficient intrinsic motivation. These challenges underscore the urgent need for curriculum-aligned digital environments that purposefully embed reasoning practices.
Objectives: the objective of this study was to develop and evaluate a GeoGebra-integrated digital worksheet to foster Grade 9 students' mathematical reasoning.
Method: the research followed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) with 32 junior high school students in Malang Regency, Indonesia. The worksheet was designed in Canva, converted into a Heyzine Flipbook, and embedded with GeoGebra-based exploratory tasks and assessments. Three mathematics education experts validated the product, and revisions were made accordingly. Data came from pre-tests, post-tests, questionnaires, and teacher interviews. Quantitative results were analyzed with descriptive statistics, while qualitative data were analyzed using Thematics Analysis.
Results: the analysis revealed that the worksheet is valid, practical, and pedagogically effective. Participants exhibited statistically significant score increases from pre-test to post-test and self-reported enhanced motivational levels, improved visual comprehension, and higher engagement. Educators attested to the instrument's pedagogical relevance and curricular congruence. Identified barriers included erratic Internet connectivity and the constrained instructional scope of a single mathematical topic.
Conclusions: the GeoGebra-integrated digital worksheet is a valid and effective tool for enhancing mathematical reasoning at the secondary school level. It holds strong potential for broader application and future research across more mathematical topics.

Keywords: Mathematical Reasoning; Digital Worksheet; GeoGebra; Geometry Lesson.

RESUMEN

Introducción: el razonamiento matemático es esencial en la educación secundaria porque sustenta la argumentación, la justificación y la resolución de problemas. Sin embargo, muchos estudiantes presentan dificultades persistentes, agravadas por la falta de recursos interactivos y la baja motivación. Esto resalta la necesidad de entornos digitales alineados con el currículo que integren de manera explícita prácticas de razonamiento.
Objetivos: este estudio tuvo como objetivo desarrollar y evaluar una hoja de trabajo digital integrada con

GeoGebra para fortalecer el razonamiento matemático de estudiantes de noveno grado.
Método: la investigación utilizó el modelo ADDIE (Análisis, Diseño, Desarrollo, Implementación y Evaluación) con 32 estudiantes de una escuela secundaria en Malang, Indonesia. La hoja de trabajo fue diseñada en Canva, convertida en un Flipbook de Heyzine e incluyó tareas exploratorias y evaluaciones basadas en GeoGebra. Tres expertos en educación matemática validaron el producto y realizaron sugerencias para su mejora. Los datos se recopilaron mediante pretest, postest, cuestionarios y entrevistas a docentes. Los resultados cuantitativos se analizaron con estadística descriptiva y los cualitativos mediante análisis temático.
Resultados: los hallazgos mostraron que la hoja de trabajo es válida, práctica y eficaz. Los estudiantes mejoraron sus puntuaciones en el postest y manifestaron mayor motivación, mejor comprensión visual y más participación. Los docentes confirmaron su pertinencia pedagógica y coherencia curricular. Se identificaron limitaciones como la conectividad inestable y el alcance reducido a un solo tema.
Conclusiones: la hoja de trabajo digital con GeoGebra es una herramienta eficaz para mejorar el razonamiento matemático y muestra potencial para una aplicación más amplia en futuros estudios.

Palabras clave: Razonamiento Matemático; Hoja de Trabajo Digital; GeoGebra; Lección de Geometría.

INTRODUCTION

Reasoning is at the core of mathematics education, connecting conceptual understanding with logical thought. Students who develop reasoning skills can apply logic and creativity in other subjects and in daily life.[1] Mathematical reasoning enables learners to reach valid conclusions when working with both general rules and specific problems.[2,3] Sugita et al.[4] emphasize that reasoning allows students to understand concepts and solve problems that mathematics presents. When instruction reduces mathematics to routine exercises, students repeat formulas without considering their meaning, limiting the growth of logical competence.[5] For this reason, reasoning is positioned as a central goal of Indonesian mathematics curricula, together with understanding, procedural fluency, proof, problem solving, communication, and attitudes.[6]

Mathematical reasoning involves identifying patterns, making conjectures, generalizing, and drawing conclusions.[7,8] The Indonesian Ministry of Education outlines stages such as formulating a conjecture, performing calculations or transformations, validating conclusions, evaluating arguments, and expressing ideas in clear language.[7,9] Despite this emphasis, research shows that many students achieve only moderate or low levels of reasoning. Ramganesh et al.[10] reported that few students reached advanced levels. Sidenvall et al.[11] found that learners identified patterns or substituted values but often failed to explain reasoning or address complex tasks.

Interviews with teachers in Malang, Indonesia, indicated challenges in three-dimensional geometry, particularly pyramids. Students lacked prerequisite knowledge, and reliance on memorized formulas limited understanding. Shaw et al.[12] observed that learners depended on formulas without grasping their purpose, which restricted flexibility. Agusantia et al.[13] also reported weak performance on pyramid word problems, indicating limited reasoning skills.

Student Worksheets remain a key learning tool in Indonesia. Well-prepared worksheets can engage students with concepts rather than formulas.[14] Effective worksheets must be structured, clear, and motivating. The growth of digital learning environments has expanded opportunities for worksheets in electronic form. Digital worksheets promote interaction between learners and content and improve learning outcomes.[15] With integrated images, animations, videos, and quizzes, they can be accessed through multiple devices.[16] They also reduce paper use and support independent learning.

GeoGebra has emerged as a widely used digital platform for mathematics instruction. It integrates geometry, algebra, and calculus in a dynamic system that supports interactive visualization.[17] Teachers can design tasks where students explore problems and manipulate representations to strengthen conceptual understanding.[18] Research indicates that using GeoGebra for three-dimensional shapes leads to improved reasoning compared to traditional textbook instruction.[19] Many GeoGebra-based digital worksheets have been developed and validated as effective.[20,21] However, few studies focus on worksheets that target reasoning in the topic of surface area and volume of pyramids, and many available resources do not meet established criteria for mathematical reasoning.

Justification and Objective: This study seeks to design and evaluate a GeoGebra-integrated digital worksheet that strengthens reasoning skills in the topic of pyramids. It addresses the need for curriculum-aligned, technology-based resources that promote reasoning as a fundamental competency in mathematics education.

METHOD

Research Design

This investigation employed a development-and-validation design situated within the iterative ADDIE instructional design framework, proceeding through the stages of Analysis, Design, Development, Implementation, and Evaluation.[22,23] At the validation phase, the study adopted a non-observational, quasi-experimental one-group pretest-posttest model, estimating learning gains attributable to the newly designed digital worksheet. Complementary descriptive components—questionnaires, structured classroom observations, and semi-structured interviews and focus-group discussions—provided additional insights into feasibility and user perceptions.

The ADDIE model, a globally acknowledged approach for instructional design, is executed through: (A) comprehensive analysis of learning needs and contextual constraints; (D1) specification of instructional objectives, formative and summative assessments, and corresponding learning activities; (D2) iterative development of instructional materials and prototypes; (I) enactment of the intervention within the target learner population; and (E) multilevel evaluation of validity, practicality, and effectiveness, with formal mechanisms for design recirculation into earlier phases.[22,23,24]

The study design was sequenced in two distinct stages: (1) development stage (ADDIE, Analysis–Design–Development) which is iterative creation, refinement, and expert validation of a GeoGebra-integrated digital worksheet addressing surface area and volume of pyramids; and (2) validation stage (ADDIE, Implementation-Evaluation), non-experimental classroom implementation with a cohort of Grade-9 students, followed by quantitative and qualitative analysis of learning outcomes.

Population and sampling

Target population

The target population comprises Grade-9 students enrolled in public junior high schools in Malang, Indonesia, who had not yet been formally introduced to the geometric properties of pyramids.

Sampling procedure and participants

We deployed cluster convenience sampling by selecting a single intact Grade-9 class from a public junior high school that fulfilled the predefined criteria and consented to take part. The analytic sample consisted of 32 learners (24 females, 8 males; chronological age 14-15 years). Inclusion criteria required students to (i) not have encountered the pyramids unit in the current academic year; (ii) have previously engaged with the areas of plane figures and the volumes of cubes and rectangular prisms; (iii) possess access to a smartphone or laptop throughout instruction; (iv) have obtained parental consent and student assent.

Expert validators and focus group

Two validators were purposefully selected to provide expertise during the Development stage: a faculty member specializing in mathematics education and a serving mathematics instructor with more than five years of experience teaching Grade-9 geometry. To form the post-implementation focus group (mini-FGD), we recruited three practitioners: the class instructor, the validator who serves as teacher, and the mathematics education specialist, all of whom possess direct instructional experience and content expertise.

Variables

Independent Variable (Intervention)

The intervention comprised exposure to a GeoGebra-integrated digital worksheet focusing on the topic of pyramids, delivered over three lesson sessions.

Primary Outcome (Effectiveness)

Participants' mathematical reasoning was evaluated using a score ranging from 0 to 16, derived from four open-ended tasks. Scoring was conducted using an analytic rubric assigning 0 to 4 points per item, rigorously aligned with five reasoning targets: (1) conjecture formulation, (2) mathematical manipulation, (3) argument justification, (4) conclusion drawing, and (5) argument validation. These targets were adapted from the competencies established by Wardhani and the PISA-2022 mathematics framework. Sub-scores corresponding to each indicator were retained for descriptive analysis.

Secondary Outcomes (Practicality/Usability)

The practicality and usability of the intervention were evaluated through scores on teacher and student questionnaires (4-point Likert scale) addressing navigation ease, clarity of directions, engagement level, aesthetic quality, and perceived usefulness. Additional qualitative data were collected via structured classroom observation notes and teacher interview/focus group discussion themes, focusing on feasibility and perceived learning support provided by the intervention.

Covariates Recorded

Gender, pretest score, and the device employed for accessing the worksheet were recorded. As a single-group design was implemented, no between-group comparisons were planned.

Data collection

Development stage (ADDIE: Analysis-Design-Development)

Need analysis (Analysis)

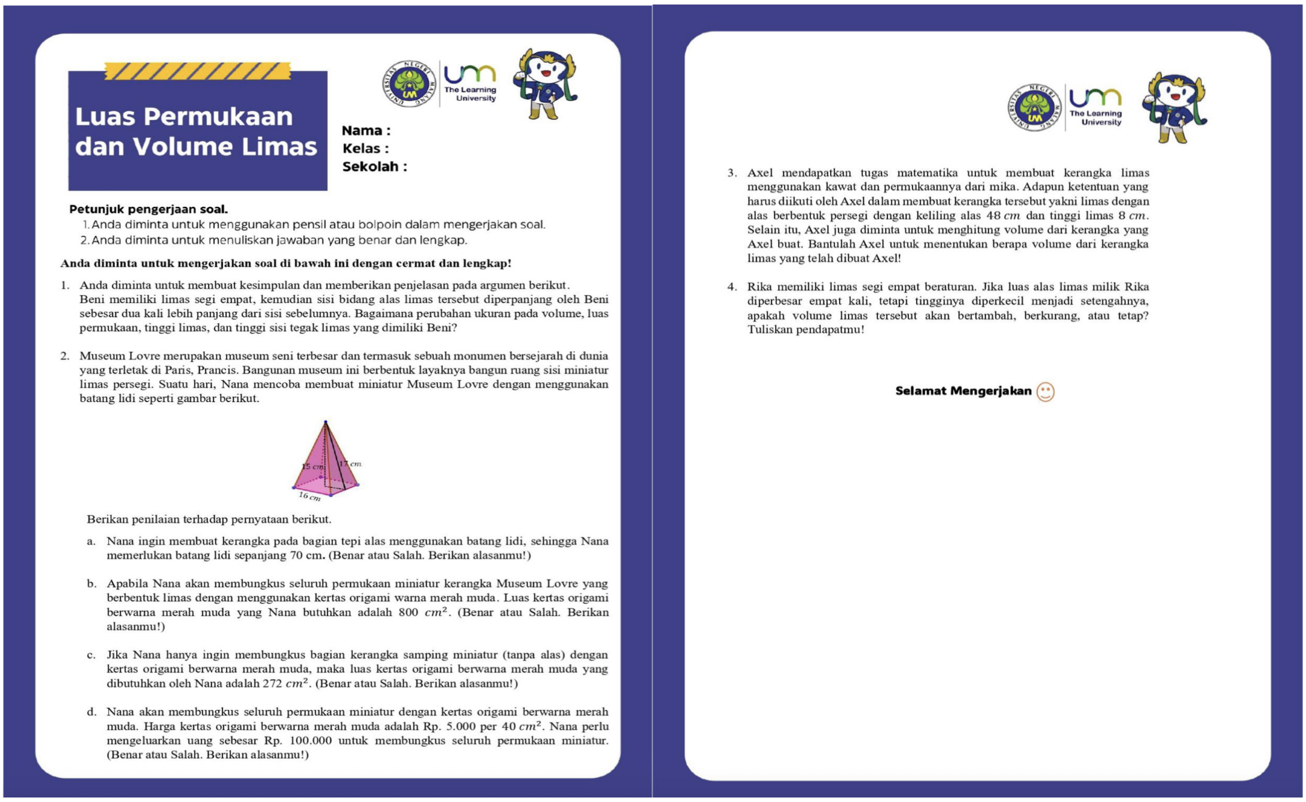
A single, semi-structured interview with a Grade-9 mathematics teacher revealed persistent difficulties in 3-D geometry, particularly in calculating surface area and volume of pyramids. Subsequent curricular and pedagogical audit verified that identified tasks aligned with, and examined the extent to which they satisfied, prevailing national learning standards.

Product design (Design)

A narrative storyboard, coupled with a detailed pedagogical specification, integrated intended learning outcomes, instructional tasks, interactive GeoGebra rectangles, and assessment rubrics according to the five reasoning dimensions identified in the analytic framework. Graphic stakeholders of the storyboard were laid out using Canva, and interactive tasks were programmed in GeoGebra.

Pre-/post-assessment formulation

The resultant four open-ended assessment items (figure 1), developed according to a blueprint matrix, conjugated ontological dimensions (nets, relationships of slant height and altitude, surface decomposition, general and special volume formulae) with epistemic reasoning indicators (conjecture, manipulation, justification, and conclusion). Two domain experts systematically scrutinized rational. The wording was subsequently revised. A 0–4 analytic rubric was developed containing anchored descriptors for all four indicators. A researcher and the classroom teacher independently coded the items for a sample of student responses. Disagreements were mediated instantly via item discussion; Cohen kappa statistics were then computed to estimate the reliability of the ratings.



Luas Permukaan dan Volume Limas

Nama :
Kelas :
Sekolah :

Petunjuk pengerjaan soal.
1. Anda diminta untuk menggunakan pensil atau bolpoin dalam mengerjakan soal.
2. Anda diminta untuk menuliskan jawaban yang benar dan lengkap.

Anda diminta untuk mengerjakan soal di bawah ini dengan cermat dan lengkap!

1. Anda diminta untuk membuat kesimpulan dan memberikan penjelasan pada argumen berikut. Beni memiliki limas segi empat, kemudian sisi bidang alas limas tersebut diperpanjang oleh Beni sebesar dua kali lebih panjang dari sisi sebelumnya. Bagaimana perubahan ukuran pada volume, luas permukaan, tinggi limas, dan tinggi sisi tegak limas yang dimiliki Beni?

2. Museum Lovre merupakan museum seni terbesar dan termasuk sebuah monumen bersejarah di dunia yang terletak di Paris, Prancis. Bangunan museum ini berbentuk layaknya bangun ruang sisi miniatur limas persegi. Suatu hari, Nana mencoba membuat miniatur Museum Lovre dengan menggunakan batang lidi seperti gambar berikut.

Berikan penilaian terhadap pernyataan berikut.

a. Nana ingin membuat kerangka pada bagian tepi alas menggunakan batang lidi, sehingga Nana memerlukan batang lidi sepanjang 70 cm. (Benar atau Salah. Berikan alasanmu!)

b. Apabila Nana akan membungkus seluruh permukaan miniatur kerangka Museum Lovre yang berbentuk limas dengan menggunakan kertas origami warna merah muda. Luas kertas origami berwarna merah muda yang Nana butuhkan adalah 800 cm^2. (Benar atau Salah. Berikan alasanmu!)

c. Jika Nana hanya ingin membungkus bagian kerangka samping miniatur (tanpa alas) dengan kertas origami berwarna merah muda, maka luas kertas origami berwarna merah muda yang dibutuhkan oleh Nana adalah 272 cm^2. (Benar atau Salah. Berikan alasanmu!)

d. Nana akan membungkus seluruh permukaan miniatur dengan kertas origami berwarna merah muda. Harga kertas origami berwarna merah muda adalah Rp. 5.000 per 40 cm^2. Nana perlu mengeluarkan uang sebesar Rp. 100.000 untuk membungkus seluruh permukaan miniatur. (Benar atau Salah. Berikan alasanmu!)

3. Axel mendapatkan tugas matematika untuk membuat kerangka limas menggunakan kawat dan permukaannya dari mika. Adapun ketentuan yang harus diikuti oleh Axel dalam membuat kerangka tersebut yakni limas dengan alas berbentuk persegi dengan keliling alas 48 cm dan tinggi limas 8 cm. Selain itu, Axel juga diminta untuk menghitung volume dari kerangka yang Axel buat. Bantulah Axel untuk menentukan berapa volume dari kerangka limas yang telah dibuat Axel!

4. Rika memiliki limas segi empat beraturan. Jika luas alas limas milik Rika diperbesar empat kali, tetapi tingginya diperkecil menjadi setengahnya, apakah volume limas tersebut akan bertambah, berkurang, atau tetap? Tuliskan pendapatmu!

Selamat Mengerjakan ☺

Figure 1. Four open-ended questions for pre-test and post-test

Expert validation of instructional materials (Phase: Development)

Panels of specialists evaluated execute content using structured four-point rating sheets. Judgments encompassed factual correctness, linguistic precision, visual uniformity, and congruence with the established reasoning objectives. Subsequent alterations encompassed enhancing unit symbol systems, refining task prompts, and inserting cognitive supports. Updated worksheets were subsequently distributed via the Heyzine Flipbook app, optimizing accessibility on mobile and computing devices.

Table 1. Research Instruments

Aspect Assessed	Instrument	Data Source
Validity	Expert validation sheets	Validators (lecturer and teacher)
Practicality	Teacher and student questionnaires	Teacher and students
	Semi-structured student interviews	Selected students
	Observation sheet	Teacher and students
Effectiveness	Pretest and posttest (same items)	Students
	Semi-structured student interviews	Selected students

Validation stage (ADDIE model: implementation and evaluation)

Field pilot (Phase: Implementation)

The instructional sequence occupied three eighty-minute periods, engaging a cohort of thirty-two learners. Session one administered a pre-test and acquainted students with the conceptual framework. In sessions two and three, learners employed the modified digital worksheet alongside embedded GeoGebra applets, undertaking model manipulation, conjecture testing, and systematic documentation of mathematical reasoning. A post-test and succinct perceptions questionnaire followed after session three.

Perceptions and practicality data collection

Immediately following the instructional sequence, learners and the lead instructor responded to a standardized usability and practicality questionnaire. A mini-focus group, lasting approximately sixty minutes, brought together the classroom instructor, a co-evaluating teaching specialist, and the lecturer; the session produced in-depth insights regarding task feasibility, interpretative clarity, and perceived instructional scaffold efficacy. Discussions were audio-recorded and subsequently transcribed. Complementary structured classroom observations gauged adherence to the design fidelity and catalogued specific patterns of student engagement.

Data Analysis (Processing)

Validity Analysis

To evaluate the validity of both the digital platform and its accompanying materials, feedback was gathered from two expert validators: a university lecturer specialising in mathematics education and an experienced secondary school mathematics teacher. Each component of the validation checklist was scored on a four-point Likert scale, allowing the reviewers to indicate varying degrees of endorsement. The resulting ratings were then processed according to following percentage formula in order to quantify the consensus around each item:[25]

$$V = \left(\frac{\sum X}{\sum X_i}\right) \times 100\%$$

Where:
V = validity percentage
∑X = total score obtained from the validators
∑Xi = maximum possible score

The level of validity was interpreted using established criteria:

- Very Valid: 80 % – 100 % (no revisions needed)
- Valid: 60 % – 79 % (minor revisions suggested)
- Less Valid: 40 % – 59 % (major revisions required)
- Invalid: < 40 % (not suitable for use)

Only products rated as "Very Valid" were used in classroom implementation.

Practicality Analysis

To evaluate the practical utility of the digital worksheet, questionnaires were administered to both educators and learners immediately following its use in the classroom. Completed surveys were then scored in the same manner as during the validity assessment, with raw totals translated into percentage figures for ease of comparison. Interpretation of these percentages was guided by a modified version of the rubric proposed by [25]:

- Very Practical: 80 % – 100 %
- Practical: 60 % – 79 %

- Less Practical: 40 % – 59 %
- Impractical: < 40 %

The practicality analysis aimed to determine the usability, accessibility, and acceptability of the digital worksheet as perceived by its users.

Effectiveness Analysis

To evaluate the effectiveness of the learning intervention, a number of statistical tests were performed on students' pretest and post-test scores. The initial task was to examine the normality of the difference scores—the gap between post-test and pretest results—using both the Shapiro-Wilk test and the Kolmogorov-Smirnov test. Researchers considered a p-value larger than 0,05 in either test as an indication that the score distribution was not meaningfully skewed or kurtotic, thereby supporting the later use of parametric techniques.(26) Once normality was established, a paired samples t-test was conducted to see if students' performance had changed in a statistically meaningful way after working with the digital worksheet.

Alongside the evaluation of statistical significance, the analysis also addressed the practical importance of the observed change by calculating effect size. Two widely adopted metrics were applied: Cohen's d and Hedges' g, with the second measure correcting Cohen's d for small samples in order to mitigate bias in the estimation. Cohen's d itself is formulated as follows:

$$d = \frac{M_{post} - M_{pre}}{SD_{pooled}}$$

Where M_{post} and M_{pre} represent the means of the post-test and pretest scores, respectively, and SD_{pooled} denotes the pooled standard deviation of both measurements. The interpretation of effect size followed Cohen's conventional thresholds: a small effect for values of $d<0{,}30$, a medium effect for $0{,}30\leq d<0{,}70$, and a large effect for $d\geq 0{,}70$.(27)

This investigation did not rely exclusively on the p-value when judging effectiveness; it also weighed how useful and instructive the observed effect might be in real educational settings. When the statistical tests returned a significant result along with a large effect size, researchers viewed that finding as robust proof that students had genuinely benefited from the digital worksheet intervention.

Qualitative Analysis of Interview Data

To complement the numerical data, the research included semi-structured interviews with a group of students who had used the digital worksheet and classroom observation. The aim was to capture subtler aspects of their experience that a survey might overlook. The interview transcripts were subjected to thematic analysis, following the procedure outlined by Braun et al.(28) The analytic process unfolded in five stages: first, the researchers read the transcripts multiple times to become intimately familiar with the material; second, they identified and tagged passages that seemed particularly meaningful; third, those initial tags were grouped into broader themes—such as motivation, engagement, and usability; fourth, the emerging themes were revisited and fine-tuned; and finally, the researchers interpreted the refined themes in light of the original research questions. These qualitative insights were then brought together with the questionnaire results, creating a triangulated view that illuminated both the practical advantages and the perceived shortcomings of the digital worksheet. By weaving together quantitative and qualitative strands, the study strengthened its overall validity and added considerable depth to the evaluation, a move that aligns with mixed-methods principles described by Creswell et al.(29).

Ethical standards

The present investigation adhered to the relevant institutional and national regulations governing research ethics, and to the provisions articulated in the Declaration of Helsinki. Approval for the study was secured from the ethical review board of the authors' university (Universitas Negeri Malang). The management of the participating school granted written authorisation. In parallel, informed consent was obtained from parents or legal guardians and assent was secured from the student subjects prior to enrolment in the research activity.(30,31,32) Participation was explicitly declared voluntary, and subjects were informed of their right to withdraw from the study at any phase without incurring any form of disadvantage or disciplinary consequences. Data were anonymised prior to analysis, retained on secured encrypted digital storage mediums, and disseminated in aggregated form only; no direct or indirect identifying information is retained within the final reports.(33,34)

RESULTS

In this section of the report, we present findings based on the analysis conducted using the ADDIE development framework which consists of five phases: Analyse, Design, Develop, Implement, and Evaluate.

Analyze Phase

The first Analyze phase guided the development of the GeoGebra-based digital worksheet and informed thoughtful considerations regarding participant characteristics and goals for instruction. This step consisted of three interconnected probes: a needs assessment, a curriculum review, and a content decomposition. These analyses addressed specific gaps within the students' conceptual understanding and ensured that the designed resource was aligned with curriculum benchmarks while remaining feasible for everyday classroom practices.

Needs Analysis

To elucidate the pedagogical and spatial difficulties encountered by junior high school mathematics instructors in Malang Regency, we administered a semi-structured interview to a veteran educator. During this term-analysis discussion, it became clear that the dominant classroom practice relied on printed worksheets with repetitive problems and lacked digital tools or collaborative learning opportunities. Thus, lesson workflows exhibited a pronounced rigidity, and pupil involvement with geometry exercises that necessitated higher-order cognitive operation proved meagre. The instructor asserted that numerous ninth-year cohorts sidestep inquiries concerning three-dimensional solids, pyramids in particular, having undergone tours of duty that reward affectless, automated reproduction over substantive exploration driven by inquisitiveness and active logical manipulation.

The instructor observed that learners' errors correlated with incomplete mastery of foundational content—including the identification and use of shape nets, the application of area formulas for planar figures, and the calculation of volume for basic solids such as cubes and rectangular prisms. Such a diagnosis is consistent with the conclusions of Hawes et al.[35], ho emphasize that strong spatial reasoning and deep geometric understanding depend on well-sequenced instruction supported by clear visual representations. Based on these insights, our team proposed the development of a digital worksheet that incorporates GeoGebra to enhance visualization, encourage hands-on exploration, and guide students through structured reasoning activities aimed at improving their mathematical thinking.

Curriculum and Content Analysis

The school adopted Indonesia's national curriculum, which was intended to give teachers more freedom in deciding how and when to present various topics. Even with this freedom on paper, day-to-day teaching is still largely influenced by the Musyawarah Guru Mata Pelajaran (MGMP), a local network of subject teachers who work together to draft schedules and select approaches that serve the needs of their community.

Operating within that established framework, the research team carried out an in-depth content analysis of the Grade 9 mathematics syllabus, focusing specifically on the geometry unit. They reviewed each learning outcome and objective to ensure that the final student worksheet would align with both national policies and the practical goals teachers encounter in the classroom. The completed digital resource zeroed in on the surface area and volume of pyramids—topics that instructors identified as essential yet especially challenging for their students.

Further, the tasks embedded in the digital worksheet were designed to reflect specific reasoning-based milestones—including conjecturing, algebraic manipulation, justification of solutions, and drawing conclusions—taken directly from the PISA 2022 mathematics framework[31] and aligned with Indonesia's own competence-centered model.

The inquiry produced a clear basis for ameliorating student disengagement by introducing validated criterion-referenced pedagogical techniques alongside concurrent emphasis on the development of both formal reasoning skills and the metacognitive regulation of reasoning strategies.

Design Phase

During design phase, the research team continue with four particular tasks: first, writing a comprehensive learning module; second, outlining a versatile digital worksheet; third, creating robust assessment tools; and fourth, putting together instruments intended for ongoing research activities.

Learning Module Development

A pedagogical module has been developed to serve as the theoretical foundation for the related digital worksheet. Its design adheres to the Teaching and Assessment Guidelines published by the Indonesian Ministry of Education, ensuring alignment with national standards. Within its pages, the module outlines each phase of the learning sequence, from the initial learning objectives to the concluding assessment, thus providing instructors with a step-by-step roadmap. The specific learning aims focus on calculating the surface area and volume of pyramids, fostering both mathematical reasoning and active student participation. This organised framework not only guarantees that classroom activities meet prescribed curriculum targets, but also gives teachers a clear, coherent pathway for implementing their lessons).

Digital Worksheet Planning

The digital worksheet built around GeoGebra was designed to deepen students' geometric understanding while sharpening their reasoning skills in a hands-on format. The sequence of activities has a clear structure designed to encourage an exploratory frame of mind. The experience opens with brief conceptual summaries that highlight the main ideas in geometry, giving learners a firm anchor before they begin. After this initial grounding, students move to the GeoGebra interface, where they can drag and rotate three-dimensional shapes, instantly seeing how those small changes affect surface area and volume calculations. These live visual adjustments are paired with open-ended questions that prompt learners to explain their thought process, defend their calculations, and evaluate the conclusions they draw.

Every element and activity within the worksheet was shaped by five guiding benchmarks of mathematical reasoning, benchmarks that draw on national evaluation standards (Wardhani, 2008) and align with broader frameworks such as the latest PISA guidelines.(31) The digital worksheet was designed to weave together these different components so that learners could both grasp the key ideas of geometry and sharpen their broader reasoning skills, in ways that align with contemporary educational guidelines.(32,33)

Assessment Tools

To evaluate how well students progressed in their mathematical reasoning, the research team prepared a set of four open-ended questions. Each item targeted the reasoning skills emphasized during the instructional sessions. By using the same questions for both pretest and post-test, the researchers obtained a measurable change attributed to the teaching intervention alone. This method aligns with the rationale provided by Stratton(34) and Hyman(35), who argue that assessment items used prior and post to an intervention should remain unchanged in order to ascertain impact in quasi-experimental frameworks.

Instrument Design

To maintain the study's integrity and relevance, multiple evaluative instruments were developed at the same time to collect and analyze data. The first component involved developing validation worksheets which guided experts through a digital evaluation of the worksheets to determine content accuracy, clarity in instructional sequencing, and overall technical execution of the given materials. These reviews proved indispensable confirming that the materials were aligned with stated learning objectives and that they adhered to recognized standards for educational quality.

In line with guidance from our expert panel, we issued semi-structured questionnaires for teachers and students to capture their views about the practical usability of the worksheet. Each survey was made up of both closed-ended questions, so we could track numerical trends, and open response sections where participants narrated detailed stories, offered suggestions, and expressed any reservations they might have had.

To measure the intervention's actual influence on learning, we then designed a battery of pretests and post-tests focused specifically on the growth we hoped to see in students' reasoning abilities, which we had identified as a key goal for the lesson.

Develop Phase

During the development of the resources, the team created and polished a GeoGebra worksheet on the surface areas and volumes of pyramids which was then presented to an expert panel for validation. This workflow is characteristic of prototyping models in instructional design research whereby specialists review and provide feedback on a continually revised draft until all criteria are satisfactorily addressed, balancing scholarly rigor with real-world classroom applicability.(36)

Digital Production and Features

The digital worksheet was created using Canva which is well known for its simple drag and drop integration of text, images, and clickable elements. The application allows instructors to design well-structured visuals which helps learners capture their attention while aiding simplified access to intricate ideas.(37,38) Moreover, we added videos and animations as well as posed 'talking' questions so that the worksheet formed a complete package, creating an integrated learning pathway which is holistic from both pedagogical and engagement perspectives.

A standout feature is the embedded GeoGebra applets, which give learners the chance to handle three-dimensional shapes directly on the screen, watch how their properties shift, and uncover geometric relationships on the fly, see figure 2. We also folded in Quizizz to offer quick assessment tasks in a game-like, self-paced format that prompts active engagement and delivers instant results, as shown in figure 3.

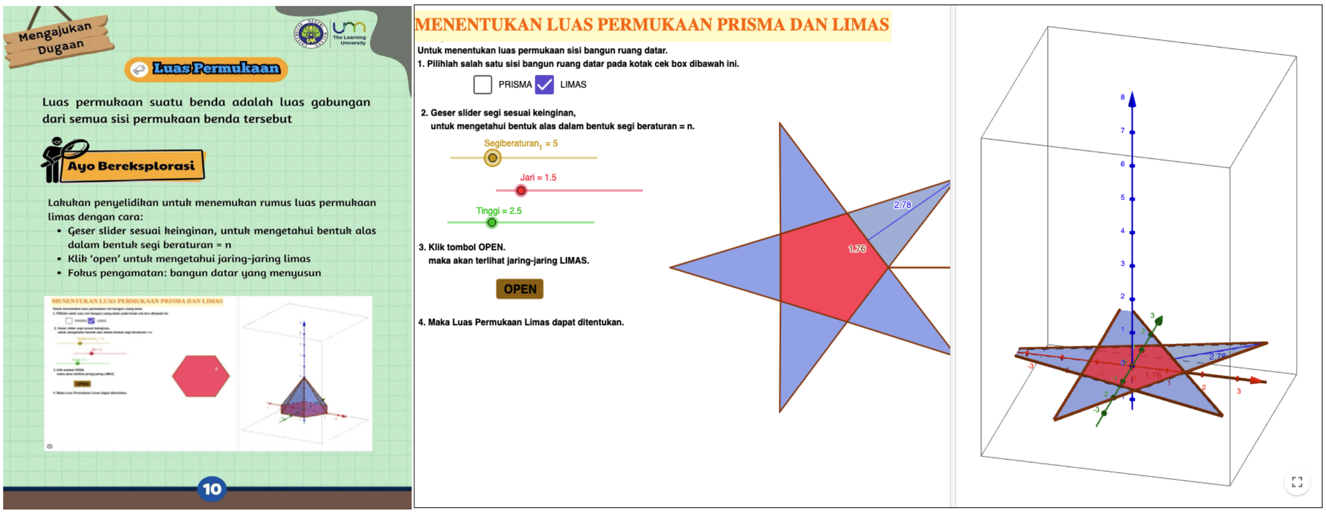


Figure 2. Embedding GeoGebra applets in the digital worksheet

The overall design incorporates reasoning-based scaffolds, with activity steps matched to where students typically are in their cognitive journey. Learners first propose conjectures, then manipulate data, justify their moves, draw conclusions, and finally verify those conclusions—an arc inspired by the indicators of reasoning set out by Treviranus(39), Kalogiannakis et al.(40), and Villaroza et al.(41) and echoed in the OECD's PISA 2022 framework.(36) Once these components were in place, we published the finished worksheet on the Heyzine Flipbook platform, ensuring that it can be browsed easily on smartphones, tablets, or computers. This method of content delivery reflects core tenets of Mayer's multimedia learning framework, as outlined in Mayer's(42) work. By prioritising flexibility, interactive features, and accessibility tailored to the needs of individual learners, the approach seeks to enhance the overall effectiveness of online education.

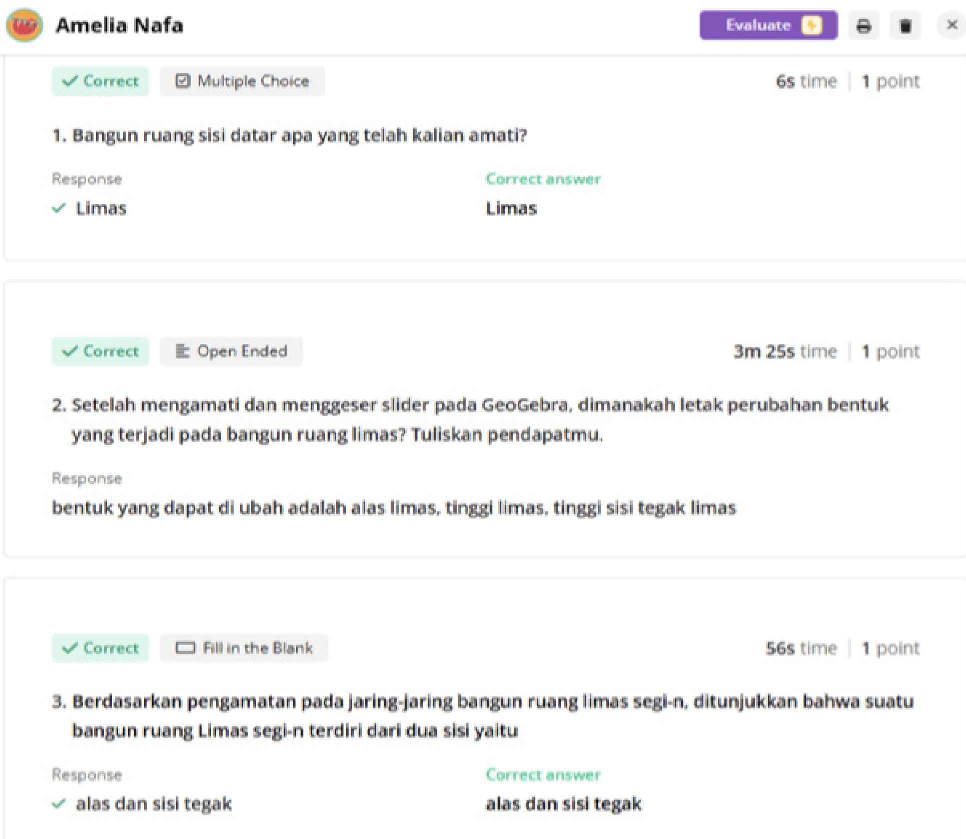


Figure 3. Assessment tasks via Quizizz

Expert Validation and Revisions

The prototype was evaluated by two subject-matter experts. Each reviewer completed a structured validation form that covered multiple dimensions, including mathematical accuracy, pedagogical organization, visual layout, language simplicity, coherence with stated learning objectives, and the presence of reasoning prompts. Incorporating their comments, the authors subsequently implemented the following changes to enhance both clarity and instructional fidelity of the material as shown in table 2.

Table 2. Summary of Revisions Based on Expert Feedback

Issue	Action Taken
Missing school identity on cover	Added school name
Unclear instructions	Revised for clarity
Incomplete explanations in examples	Included formula descriptions
Misaligned commands and formatting	Standardized according to SPOK and grammar rules

These revisions aligned with instructional material design standards and ensured that the product supported both pedagogical integrity and user comprehension.(43,44)

Validation Results

Following revision, the product and its associated instruments were reassessed. The average validity scores are summarized in the table 3 below.

Table 3. Validation Scores

Instrument	Average Validity (%)	Category
Learning Module	98 %	Very Valid
Digital Worksheet	94 %	Very Valid
Student Questionnaire	89 %	Very Valid
Pre/Post-test Items	93 %	Very Valid

Every instrument in the study attained the “Very Valid” classification, exceeding the recommended 80 percent benchmark for effective classroom application.(25) Such a result indicates that the digital worksheet along with its supplementary resources possesses a robust quality that makes it suitable for immediate use by teachers and students alike. This positive validation further aligns with earlier research conducted by Nurulaini et al.(45), which found that digital worksheets featuring interactivity, structured reasoning prompts, and repeated feedback loops tend to receive comparably high validity ratings from subject-matter experts.

Implement Phase

The implementation phase was designed to evaluate the efficacy of the GeoGebra-integrated digital worksheet when deployed in an actual classroom setting, moving the inquiry beyond theoretical assumptions to empirical observation. The real-world trial took place at a public junior high school located in Malang Regency and involved 32 ninth-grade learners, comprising 8 boys and 24 girls. Over the course of three lessons, the team followed established guidelines for instructional pilot studies that are part of the design-based research approach.(46,47,48)

Classroom Implementation Structure

This instructional sequence was implemented over three consecutive sessions, each session intended to advance students’ mathematical reasoning in a cumulative and incremental manner. In the first session, learners began with a pretest composed of four open-ended questions that targeted their initial understanding of pyramid surface area and volume. This brief assessment served as both a diagnostic tool and a light introduction to the content. In the same session, instructors outlined the specific learning objectives and provided an overview of the digital worksheet that would guide the work in the sessions to come. The subsequent session shifted from explanation to experiential learning.(49,50,51) Each participant engaged with a digital schematic embedded within Device Applets that visualized key geometric properties, thereby fostering a direct, manipulable interaction with the constructs under study. As they manipulated the applets, the interactive elements guided them through a logical sequence: forming conjectures, fine-tuning the visual models, defending their reasoning, and finally arriving at well-grounded conclusions. This learner-centred approach, reinforced by the capabilities of the digital tools, typified the session and resonated with findings from Serin's[52] and the Hawes's[31] work on what effective higher-order learning environments should offer. In the third session, a post-test was administered with the same structure as the pre-test to provide a clear comparison of each student's growth in understanding. After completing the assessment, learners then answered a feedback questionnaire that explored the worksheet's usability, looking at visual clarity, ease of navigation, and overall functionality, as well as its impact on the depth of their mathematical reasoning.

Observations and Challenges During Implementation

During the phase of implementation, researchers recorded a range of logistical and instructional observations. Many students expressed excitement about the digital worksheet, with particular interest in the integrated GeoGebra tasks. These features transformed abstract geometric ideas into concrete forms they could manipulate and observe. However, a number of technical hitches arose. Some students showed up without a smartphone, and others faced patchy network coverage that blocked access to online activities such as Quizizz. Such problems reinforce long-standing concerns about digital equity in technology-rich classrooms, as noted by Clement and Battista, Dijk et al.[48,49].

Moreover, even though the worksheet was designed to be clear, a few students still needed extra help to navigate the platform. This uneven level of digital skill suggests that a brief orientation session or immediate teacher backup should be built into the launch of any new tool, a recommendation highlighted.[50] Despite these difficulties, curiosity remained high, and student performance on tasks requiring logical reasoning showed steady improvement over the lessons. Many students reported that the worksheet's interactive visuals clarified geometric relationships and the formulas that describe them. That observation echoes studies by Mayer[51], Nelson-Fromm et al.[52] and Pedersen et al.[53], that GeoGebra can strengthen learners' mathematical reasoning.

Evaluate Phase

Throughout the evaluation period, the investigation examined the degree to which the paired digital worksheet and GeoGebra environment supported students in reasoning about the surface area and volume of pyramids. Central to the inquiry was whether the tool could be integrated into everyday classroom practice without disruption, while simultaneously producing noticeable improvements in student understanding. As a result, the inquiry focused on two principal dimensions: practicality and educational impact. In examining practicality, the research team collected user feedback concerning the ease of navigating the interface, the clarity with which mathematical ideas were conveyed, and the degree to which both instructors and learners regarded the resource as genuinely beneficial. Effectiveness, by contrast, relied on hard data: researchers compared pretest and post-test scores using both descriptive statistics and more robust inferential techniques in order to measure actual learning gains. The sections that follow summarize what was discovered in each of these two areas.

Practicality Test

The practicality of the GeoGebra-based digital worksheet was gauged using feedback collected from the mathematics instructor as well as the students who worked through the material.[54,55,56,57] According to the data summarized in table 4, the teacher awarded the resource a perfect score of 100 per cent, classifying it as "Very Practical." The group of learners, however, averaged a score of 79 per cent, placing their assessment in the "Practical" category. Across all the feedback collected, respondents consistently highlighted the worksheet's user-friendliness, clear instructions, and pedagogical alignment as particular strengths.

Table 4. Practicality Results

Respondent	Score (%)	Category
Teacher	100 %	Very Practical
Students	79 %	Practical

Qualitative comments offered by the students echoed this quantitative evaluation. Several students mentioned that the embedded GeoGebra tools introduced a level of interactivity they had not expected, transforming the material into something both visually appealing and engaging. Participants recognized the innovative character of the digital tool and observed that the dynamic graphics provided significant clarity to geometric ideas that had been perceived as abstract. Such comments support the theoretical constructs of user-centered design and technology-mediated pedagogy, suggesting that the worksheet may be adopted as a regular component of instructional practice within the classroom.

Effectiveness Test

The following section summarises the statistical analysis undertaken to determine whether the GeoGebra-driven digital worksheet enhanced students' reasoning skills on surface area and volume problems involving pyramids. To arrive at this judgement, researchers first collected baseline performance data from learners before they used the tool, then repeated the assessment afterwards. The subsequent analysis employed a range of methods including descriptive statistics, normality tests, paired-samples t-tests, correlation studies, and effect size calculations, to examine the change in scores.

Prior to conducting any inferential analyses, preliminary descriptive statistics were computed to provide a clear overview of student performance. Table 5 reveals that the average pretest score was 35,84, with a standard deviation of 24,28, indicating considerable variability in initial knowledge. In contrast, the mean score on the post-test rose sharply to 57,16, accompanied by a reduced standard deviation of 20,62. This 21,31-point gain in the average score points to a significant enhancement in student comprehension and problem-solving ability attributable to the implementation of the digital worksheet.

Table 5. Descriptive Statistics for Pretest and Posttest (N = 32)

Measure	Mean	Std. Deviation	Std. Error Mean
Pretest	35,84	24,283	4,293
Posttest	57,16	20,616	3,645

This descriptive overview indicates that student performance showed noticeable gains after the intervention was applied. However, to establish whether this improvement reaches statistical significance and can be reasonably expected to apply beyond this particular sample, inferential analyses will need to be conducted.

Before proceeding with parametric inferential analyses, it is important to verify that the assumption of normality holds for the difference scores—namely, the post-test scores minus the pretest scores. To that end, the Shapiro-Wilk and Kolmogorov-Smirnov tests were performed, and the results appear in table 6.

Table 6. Tests of Normality for Difference Scores

Test	Statistic	df	Sig.
Kolmogorov-Smirnov	0,104	32	0,200*
Shapiro-Wilk	0,960	32	0,276

Note: * This is a lower bound of the true significance.

The Shapiro-Wilk p-value of 0,276 and the Kolmogorov-Smirnov p-value of 0,200 both exceed the conventional alpha level of 0,05. So, there is no statistical evidence to reject the assumption of normality for the difference scores. This finding validates the application of a paired-sample t-test in subsequent analyses aimed at assessing the intervention's effectiveness.

A paired samples correlation analysis was conducted to evaluate the relationship between students' pretest and post-test scores. The data displayed in table 7 reveal a correlation coefficient of r = 0,444, a value that reached statistical significance (p = 0,011, two-tailed). This moderate positive correlation implies that learners who achieved higher marks on the pretest also outperformed their peers on the post-test, even though every student showed measurable progress during the intervention.

Table 7. Paired Samples Correlation

Variables	N	Correlation	Sig. (2-tailed)
Pretest & Post-test	32	0,444	0,011

This correlation also indicates consistency in relative performance while confirming that individual improvements varied depending on initial ability levels.

To determine whether the increase in scores from pretest to post-test was significant, a paired samples t-test was conducted. The results are presented in table 8.

Table 8. Paired Samples t-Test

Pair	Mean Difference	Std. Dev.	Std. Error	95 % CI Lower	95 % CI Upper	t	df	Sig. (2-tailed)
Pre - Post	-21,312	23,873	4,220	-29,919	-12,706	-5,050	31	< 0,001

https://doi.org/10.56294/saludcyt20252137 ISSN: 2796-9711

The statistical analysis produced a t-value of -5,050 based on 31 degrees of freedom, yielding a p-value smaller than 0,001. These figures suggest a robust improvement in learners' mathematical reasoning abilities. Moreover, the 95 % confidence interval for the mean difference excluded zero, which strengthens the inference that the gain in performance was not merely a random occurrence.

Such evidence confirms that the GeoGebra-assisted digital worksheet improved students' understanding and reasoning about geometric problems related to pyramids.

Statistical significance is only one piece of the puzzle; it does not automatically translate into something educators can use in practice. In order to provide a clearer picture of how much difference the intervention actually made, we calculated effect sizes using Cohen's d and Hedges' g. Both of these measures take the average change and divide it by the standard deviation, which allows us to compare the result meaningfully across studies with different sample sizes and variances. The results appear in table 9.

Table 9. Paired Samples Effect Sizes

Effect Size Measure	Point Estimate	95 % CI Lower	95 % CI Upper	Interpretation
Cohen's d	-0,893	-1,299	-0,476	Large
Hedges' g	-0,871	-1,267	-0,465	Large

Both Cohen's d of -0,893 and Hedges' g of -0,871 comfortably meet the conventional threshold for a large effect size.[26] This finding confirms not just statistical significance but also practical significance: the intervention achieved a meaningful change that teachers are likely to notice in the classroom. The negative sign in both estimates signals that participant scores increased from pre-test to post-test rather than indicating any sort of decline.

A comprehensive analysis—including descriptive statistics, correlation matrices, significance tests, and effect-size calculations—indicates that students' geometric reasoning improved noticeably after working through a GeoGebra-supported digital worksheet. Mean scores on the follow-up assessment exceeded those on the pre-test by over twenty-one points; this difference reached conventional significance levels and remained consistent across the full sample. Although the observed correlation coefficient was moderate, the larger effect-size statistic underscores that the shift may matter in practical classroom planning.

These results hint that instructional environments built around interactive resources such as GeoGebra can engage learners more deeply and illuminate challenging geometric ideas. The worksheet's carefully orchestrated progression—moving students through conjecturing, shape manipulation, conclusion drawing, and justification—appears to have sharpened participants' higher-order thought processes.

Such observations fit well with earlier studies showing that technology-enabled exploration promotes logical reasoning and richer understanding in mathematics.[58,59,60,61,62] Importantly, the greatest gains occurred among learners who previously struggled with spatial visualization or routine procedures, suggesting that a single digital format can adapt to varied educational profiles.

DISCUSSION

This section summarizes the results of designing and validating a GeoGebra worksheet aimed at improving students' reasoning in calculating the surface area and volume of pyramids. The presentation follows the iterative five-stage ADDIE framework: Analysis, Design, Development, Implementation, and Evaluation.

Analyze Phase

These findings align with [59] assertion that robust spatial skills form the backbone of successful engagement with 3D geometry. Furthermore, the habitual use of traditional paper-and-pencil worksheets appeared to dampen curiosity and diminish student involvement, resulting in a superficial, almost formulaic understanding of the topic.[60] To address this shortcoming, the researcher conceived a GeoGebra digital worksheet, confident that the software's interactive platform would encourage visualization, hands-on manipulation, and a more substantive reasoning process. With GeoGebra, students can spin, measure, and break apart three-dimensional shapes whenever they please. This hands-on capability helps learners switch between the abstract and the concrete better than when they use pencil and paper alone.

Designing the worksheet relied on time-tested reasoning steps—making conjectures, manipulating objects, justifying answers, and reaching conclusions—that appear in both the OECD's PISA mathematics framework analysis of essential 21st-century skills. Aware that interactive tools can overwhelm students without proper scaffolding,[61] we arranged the tasks in a graduated sequence and added concise instructions and teacher support. The analysis phase revealed both conceptual weaknesses and pedagogical hurdles, and those insights guided the creation of a reasoning-focused, technology-based instructional resource.

Design Phase

Guided by the principles of the curriculum and a recent needs assessment, the design phase prioritised the creation of instructional resources aimed at strengthening learners' mathematical reasoning. The team produced two central artefacts: a comprehensive teaching module intended as a pedagogical reference for educators and a working prototype of a GeoGebra-enhanced digital worksheet. Every instructional resource was mapped to five key reasoning indicators—making conjectures, executing manipulations, reaching conclusions, building arguments, and assessing solutions—so that the entire sequence would reinforce the same logical thread.

To gauge any shifts in comprehension, the project team inserted pre- and post-test items featuring the same constructed-response questions, following the alignment strategy described by Fraenkel et al.[62] for measuring teaching impact. In addition, they paired these tests with expert validation rubrics and perception surveys aimed at both instructors and learners; these tools ensured that content remained valid, instructions stayed clear, and the entire setup worked smoothly in classroom settings.

This design methodology draws on the TPACK framework[63] to highlight the interplay of subject matter, teaching methods, and digital resources. In sum, the creation process has yielded an instructional prototype that aligns with curricular goals, rests on sound theory, and maintains pedagogical clarity, all while making reasoning the central target for student growth.

Develop Phase

In the prototyping phase, the GeoGebra-enhanced digital worksheet was realized within the Canva environment, which was selected for its user-friendliness and adaptable layout capacities. Prior pedagogical initiatives have documented Canva's utility for educational technology applications, attributing its success to deliberate composition of coherent vistas and straightforward user paths.[64,65,66] The worksheet was constructed around a sequential reasoning cycle in which learners propose conjectures, manipulate digital artefacts, substantiate decisions, and evaluate insights. The cycle is congruent with the reasoning architecture advanced by PISA 2022 and promotes increasing cognitive commitment in the spirit of Polya[67] and Lithner[68].

GeoGebra's dynamic 3D environment permits unrestricted translation and rotation of components, affording students immediate interaction with geometriese relationships. Evidence from comparable inquiries affirms that interactive imaging of this kind consolidates both reasoning competence and spatial acuity, and the effect is pronounced in three-dimensional geometric contexts.[69,70] The reported effect is consistent with Mayer's cognitive theory of multimedia learning,[71] which advocates for the minimization of extraneous cognitive demand. Thus, Canva's restrained user interface was designed to remove distractions and focus the learners' cognitive resources on core mathematical constructs, thus applying the theory's core tenets in practice.

The preliminary reactions obtained from the target population revealed that the worksheet's configuration effectively fostered cognitive engagement while rendering physical concepts more tangible. These findings corroborate the data presented by Nelson-Fromm et al.[72], which demonstrated that strategically orchestrated digital environments can mitigate the cognitive distance between multimodal representation and conceptual mastery. Conversely, the inquiry by Pedersen et al.[73] identified cases where inadequately scaffolded digital interventions exacerbate ambiguity, thereby underscoring the instrumentality of meticulous design scrutiny. The pronounced engagement observed in this inquiry implies that the synthesized platform—comprising the dynamic capabilities of GeoGebra and the creative flexibility of Canvas—successfully calibrated multimodal attractiveness with pedagogical integrity.

Subsequent to the analysis of student feedback, the authorial team engaged a senior mathematics lecturer and a pedagogically experienced mathematics educator to perform iterative refinement of the prototype instrument. Through triangulated scrutiny, the experts modified instructional lexicon, standard units, mathematical notation, and navigational scaffolds. The ensuing validation engagement yielded a validity index of 94 %, thus attesting to a robust conformance to the statutory curriculum benchmarks and to the delineated epistemic objectives. These indices approximate those reported by Setiyani et al.[74], who documented comparable convergence in the validation of purpose-driven digital mathematical resources.

An initial round of practicality testing yielded a flawless 100 per cent rating from the instructor and an average of 78 per cent from five participating students, thus satisfying Riduwan's[25] benchmarks for effective implementation. Nevertheless, several students pointed out that switching between different software environments proved challenging, and they requested more straightforward directions, a comment that highlights the necessity of intuitive interface design.[75] Although the limited number of respondents constrains wider applicability, the prototype showed high standards in both pedagogy and aesthetic execution, indicating it could serve as a solid foundation for larger-scale digital learning initiatives that emphasize reasoning in mathematics instruction.

Implement Phase

After undergoing validation, the GeoGebra digital worksheet was deployed in a ninth-grade class of thirty-two students during the study's implementation phase. The intervention unfolded over three consecutive periods: the first served as a pre-test baseline, the second invited students to work with the interactive module, and the final session closed with a post-test and structured learner feedback. Taken together, these measures suggest that the worksheet fostered an engaging, visually supported context in which the core mathematical ideas could be explored meaningfully. Students expressed a strong positive response to the technological component, with specific praise for the embedded GeoGebra applets that increased both their interest and their comprehension of the subject matter.

Yet, alongside these encouraging results, the rollout was not without its difficulties. The chief hurdle stemmed from uneven access to personal devices. Not every participant brought a smartphone—the gateway through which the digital worksheet was reached—and this lack of uniformity meant that some learners could not engage as deeply as we had hoped. While many decision-makers promote the Bring Your Own Device (BYOD) model as a cost-saving strategy, the reality is that it tends to ignore the significant socio-economic differences that affect which devices families can afford.[76] Given this insight, schools would be wise to consider alternatives such as shared carts of laptops or tablets, or even loaner programs, so that every student has the same opportunity to participate in digital learning.

Limited class time presented a clear challenge during the rollout of the new digital intervention. Students often ran out of time to finish all planned activities during the allocated lesson, and this shortfall stemmed partly from their still-maturing familiarity with the digital tools and partly from the high cognitive load demanded by the reason-based tasks. Zhang et al.[20] and [77] point out that meaningful engagement with interactive worksheets—especially those built on dynamic systems like GeoGebra—requires deliberate pacing and tiered scaffolding, yet those supports were applied unevenly during the pilot.

Unreliable internet access further compounded the issue. Some learners experienced lags so severe that GeoGebra's interactive elements stalled, while others could not log in at all to quizzes run on services such as Quizizz. This observation echoes,[78] who reported that patchy digital networks still hinder effective technology use in many Indonesian classrooms. Although GeoGebra offers an offline mode, the repeated connectivity setbacks highlight the importance of teachers proactively securing and keeping offline backups ready whenever stable Internet cannot be assured.

Because the schedule was already compressed, many students did not have space in the lesson to walk their peers through their problem-solving steps or to explain the reasoning behind the conclusions they reached on the worksheet. As a result, the session forfeited key moments for formative feedback and collaborative peer learning. Such presentations strengthen students mathematical reasoning and argumentation skills and they encourage the metacognitive reflection needed for solidly internalising concepts. Absent that reflective dialogue, the initiative proved markedly less effective than it otherwise might have been.

Evaluate Phase

In assessing the GeoGebra-linked digital worksheet, we undertook a systematic evaluation that focused on its pedagogical effectiveness, user-friendliness, and general instructional quality. The appraisal drew on multiple sources of evidence: quantitative scores from validation rubrics, qualitative responses from teacher and student questionnaires, and achievement data from pre-test and post-test comparisons.

Practicality Evaluation

To determine how practical the worksheet is in real classroom settings, we turned first to the users themselves. Educators and learners assigned an average score of 79 per cent, categorising the resource as "practical." The 79 per cent score highlights users' appreciation for clear instructions, intuitive navigation, and a design that aligns with their learning goals. This rating exceeds the 70 per cent benchmark suggested by [32], which he identifies as the minimum threshold for educational materials to be considered suitable for classroom use. However, the score stops just short of the 80 per cent mark, indicating specific areas for enhancement—most notably, the digital interface could benefit from further refinement, and additional scaffolding should be provided to assist those students who are still developing their digital literacy.

Effectiveness Evaluation

This statistical result suggests that the observed enhancement in students' performance exceeds what might be expected by chance alone, and it translates into a discernible improvement that teachers would likely notice in everyday classroom tasks. Consequently, the data strengthen the claim that the use of structured worksheets supported by dynamic visualisation genuinely bolsters learners' mathematical reasoning.

These observations align with results from [79,80], who reported similar benefits when GeoGebra was introduced into instructional sequences; their participants demonstrated marked gains in both conceptual understanding and spatial reasoning. Complementary evidence provided by [81] underscores that contemporary learners consistently encounter fewer barriers to three-dimensional geometry once dynamic visual instruments are at hand. By allowing students to rotate solids, manipulate vertices, and watch quantitative properties fluctuate in real time, those instruments alleviate the conceptual distance that usually makes the topic seem so abstract.

Qualitative Reflections from Student Feedback

Further clarity about the digital worksheet's performance came once researchers examined student surveys and conducted follow-up interviews, revealing several notable advantages. At the top of that list was the way the tasks lined up with key reasoning indicators. Learners consistently pointed out that the step-by-step exercises—particularly those prompting them to make conjectures, offer justifications, and reach conclusions—encouraged a clearer and more methodical thought process. This feedback supports the view that a digital resource must be crafted intentionally around cognitive objectives that correspond with recognised models of mathematical reasoning.[82,83]

Alongside that cognitive alignment, many learners reported an uptick in motivation while using the worksheet, attributing the boost to its interactive elements and the rapid feedback provided by GeoGebra.[84,85] underscore the core principles of Self-Determination Theory, identifying feelings of autonomy and competence as primary drivers of student engagement. Alongside those elements, participants consistently cited the quality of visuals and careful design as factors that elevated their overall learning experience. Created in Canva, the worksheet offers a clean, inviting layout that learners reported kept them focused and involved from beginning to end.

The observation resonates with Mayer's[60] cognitive theory of multimedia learning, which advises designers to limit extraneous load by ensuring every graphic serves a clear, coherent purpose. User comments indicated that the interactive sheet maintained mental activity by guiding students through each reasoning stage, while its tidy, appealing presentation also connected with their emotions.

CONCLUSIONS

This investigation aims to design and validate a GeoGebra-embedded digital worksheet intended to deepen ninth graders' mathematical reasoning within the domain of solid geometry. Employing the ADDIE design framework, the inquiry produced an instructional product that interlinks dynamic geometric visualizers, sequenced problem tasks, and reasoning-promoting exercises. Data analysis suggests that the systematic coupling of technology with instructional design fidelity fosters heightened learner engagement and enables consolidation of geometric concepts. Teacher engagement and curriculum alignment appeared as critical factors when digital tools were introduced. Therefore, systematic professional development and integration with written syllabi are necessary prerequisites.

On a wider scale, the investigation exemplifies the scalability of digital worksheets as leveraged instruments for advancing mathematical reasoning across heterogeneous educational milieu. Rigor of design is necessary, though insufficient: infrastructural robustness, pre-service and in-service teacher training, and seamless intersection with preexisting pedagogic habits must converge to fulfil the promise of the worksheet. Future research may adapt similar instruments to diverse educational contexts, including institutions with limited technological resources. Extension to larger demographic cohorts, coupled with longitudinal or triangulatory methodology, would refine comprehension of the mid- to long-term repercussions of digital, reasoning-dominant instruction on learner performance.

BIBLIOGRAPHIC REFERENCES

1. Hačatrjana L, Namsone D. Breaking Down the Concept of Students' Thinking and Reasoning Skills for Implementation in the Classroom. J Intell 2024;12(11):109.

2. Öz T, Çiftci Z. Mathematical Reasoning Activity: Compare, Generalize and Justify. Necatibey Eğitim Fakültesi Elektron Fen ve Mat Eğitimi Derg 2024;18(2):291–323.

3. Smit R, Dober H, Hess K, Bachmann P, Birri T. Supporting primary students' mathematical reasoning practice: the effects of formative feedback and the mediating role of self-efficacy. Res Math Educ 2023;25(3):277-300.

4. Sugita G, Nurhayadi N, Sukayasa S. Ability Reasoning Mathematical Students on Solving Problem. Int J Curr Sci Res Rev 2024;07(12).

5. Jonsson B, Granberg C, Lithner J. Gaining Mathematical Understanding: The Effects of Creative Mathematical Reasoning and Cognitive Proficiency. Front Psychol 2020;11.

6. Sufyadi S, Lambas, Rosdiana T, Rochim FAN, Novrika S, Iswoyo S, et al. Panduan Pembelajaran dan Asesmen. Jakarta: Pusat Asesmen dan Pembelajaran; 2021.

7. Baiduri B. Students' mathematical reasoning in mathematics problems solving. AMCA J Educ Behav Chang 2021;1(2):61-8.

8. Santos L, Mata-Pereira J, da Ponte JP, Oliveira H. Teachers' Understanding of Generalizing and Justifying in a Professional Development Course. Eurasia J Math Sci Technol Educ 2022;18(1):em2067.

9. Raditya A, Saputra NN. Question analysis in indonesians' new curriculum secondary mathematics textbook. Desimal J Mat 2022;5(3):353-62.

10. Ramganesh E, Reddy TS. Logical Reasoning of School Students as Predictor of their Academic Performance in Mathematics. Int J Manag. 2021;12(1):707-12. http://iaeme.com/Home/journal/IJM707editor@iaeme.comhttp://www.iaeme.com/ijm/issues.asp?JType=IJM&VType=12&IType=1JournalImpactFactor

11. Sidenvall J, Lithner J, Jäder J. Students' reasoning in mathematics textbook task-solving. Int J Math Educ Sci Technol. 2015;46:533-52. https://api.semanticscholar.org/CorpusID:61658784

12. Shaw ST, Pogossian AA, Ramirez G. The mathematical flexibility of college students: The role of cognitive and affective factors. Br J Educ Psychol. 2020;https://api.semanticscholar.org/CorpusID:210982190

13. Agusantia D, Nurlaelah E. Mathematics Analogy Reasoning Ability of Junior High School Students in Solving Problems of Pyramid. Mathline J Mat dan Pendidik Mat 2023;8(3):989-1004.

14. Burkholder E, Mohamed-Hinds N, Wieman C. Evidence-Based Principles for Worksheet Design. Phys Teach 2021;59(6):402-3.

15. Khastini RO, Rohmah WS, Sahida AN. The Effectiveness of the e-Student Worksheets to Improve Students' Learning Outcomes and Critical Thinking Skills on Digestive System Concepts. Int J Biol Educ Towar Sustain Dev 2023;3(1):52-61.

16. Serth S, Teusner R, Renz J, Uflacker M. Evaluating Digital Worksheets with Interactive Programming Exercises for K-12 Education. In: 2019 IEEE Frontiers in Education Conference (FIE). IEEE; 2019. page 1-9.

17. Hohenwarter M, Fuchs KJ. Combination of dynamic geometry, algebra and calculus in the software system GeoGebra. Zdm. 2004;128-33. https://api.semanticscholar.org/CorpusID:15254420

18. Haciomeroglu ES. Visualization Through Dynamic Geogebra Illustrations. In: Model-Centered Learning. Rotterdam: SensePublishers; 2011. page 133-44.

19. Villaroza RD, Villaroza RC, Canoy JCD, Macalong ERN, Coronado WA. Exploring the Impact of GeoGebra on Mathematical Proficiency and Inductive Reasoning Ability in Geometry Students of MSU N - Integrated Developmental School. Int J Sci Manag Stud 2023;128-42.

20. Zhang Y, Wang P, Jia W, Zhang A, Chen G. Dynamic visualization by GeoGebra for mathematics learning: a meta-analysis of 20 years of research. J Res Technol Educ 2025;57(2):437-58.

21. Hapsari MR, Nurcahyo A, Toyib M. Development of Learner Worksheets Assisted by Geogebra Software on Trigonometry Material for Class X. J Medives J Math Educ IKIP Veteran Semarang 2024;8(3):402.

22. Nichols Hess A, Greer K. Designing for Engagement: Using the ADDIE Model to Integrate High-Impact Practices into an Online Information Literacy Course. Comminfolit 2016;10(2):264.

23. Allen WC. Overview and Evolution of the ADDIE Training System. Adv Dev Hum Resour 2006;8(4):430-41.

24. Suratnu R. The adoption of the ADDIE model in designing an instructional module: The case of malay language remove students. IJIET (International J Indones Educ Teaching) 2023;7(2):262-70.

25. Riduwan. Skala pengukuran variabel-variabel penelitian. Bandung: ALFABETA; 2018.

26. Sharma LR, Jha S. Applying Major Parametric Tests Using SPSS in Research. Int Res J MMC 2023;4(2):85-97.

27. Nissen JM, Talbot RM, Nasim Thompson A, Van Dusen B. Comparison of normalized gain and Cohen's <math display="inline"> <mrow> <mi>d</mi> </mrow> </math> for analyzing gains on concept inventories. Phys Rev Phys Educ Res 2018;14(1):010115.

28. Braun V, Clarke V. Thematic Analysis: A Practical Guide. London: SAGE Publications Ltd.; 2012.

29. Creswell JW., Poth CN. Qualitative inquiry and research design: Choosing among five approaches. 2nd ed. Sage publication; 2007.

30. Hawes Z, Moss J, Caswell B, Naqvi S, MacKinnon S. Enhancing Children's Spatial and Numerical Skills through a Dynamic Spatial Approach to Early Geometry Instruction: Effects of a 32-Week Intervention. Cogn Instr 2017;35(3):236–64.

31. OECD. PISA 2022 Assessment and Analytical Framework. OECD; 2022. https://www.oecd.org/en/publications/pisa-2022-assessment-and-analytical-framework_dfe0bf9c-en.html

32. Riwayati S, Destania Y. Design of Internet Integrated Students Worksheet for Developing the Ability of Mathematical Reasoning. In: Proceedings of the International Conference on Educational Sciences and Teacher Profession (ICETeP 2018). Paris, France: Atlantis Press; 2019.

33. Jones K, Mackrell K, Stevenson I. Designing Digital Technologies and Learning Activities for Different Geometries. 2009. page 47–60.

34. Stratton SJ. Quasi-Experimental Design (Pre-Test and Post-Test Studies) in Prehospital and Disaster Research. Prehosp Disaster Med 2019;34(6):573–4.

35. Hyman R. Quasi-Experimentation: Design and Analysis Issues for Field Settings (Book). J Pers Assess 1982;46(1):96–7.

36. Plomp T, Nieveen N. An Introduction to Educational Design Research. In: Proceedings of the seminar conducted at the East China Normal University, Shanghai (PR China), November 23-26, 2007. 2010.

37. Pinandhita F, Yasin MH bin M. Optimizing Students' Reading Skills through Microlearning with Canva: A Digital Approach in ELT. IJORER Int J Recent Educ Res 2025;6(2):470–81.

38. Riyanto MATP, Putri SJD. The Utilization of Canva Application in Innovative Learning For Elementary School Teachers. Expert Net Explor J Technol Educ Trends 2025;1(2):61–6.

39. Mueller MF, Maher CA. Promoting equity through reasoning. Teach Child Math 2010;16(9):540–7.

40. Hirschhorn DB, Thompson DR. Technology and Reasoning in Algebra and Geometry. Math Teach 1996;89(2):138–42.

41. Anwar L, Mali A, Goedhart M. Formulating a conjecture through an identification of robust invariants with a dynamic geometry system. Int J Math Educ Sci Technol. 2024;55(7):1681–703. https://doi.org/10.1080/0020739X.2022.2144517

42. Mayer RE. The Cambridge handbook of multimedia learning, 1st Edition. 2005. https://api.semanticscholar.org/CorpusID:267932905

43. Mulat A, Sudarsono S, Salam U. Instructional Design for Reading Comprehension Teaching Materials. Int J Learn Instr 2024;6(1):7–15.

44. Morrison GR, Ross SM, Kemp JE. Designing Effective Instruction. 5th Edition. Jossey-Bass, An Impr Wiley. 2006;https://api.semanticscholar.org/CorpusID:61038124

45. Isna Amaliya, Aida Suraya, Sumaji, Sri Utaminingsih, Pratama H. The Effectiveness of Digital Interactive Media Worksheets in Improving Elementary School Students' Mathematical Literacy. Stud Technol Educ 2024;3(3):1-8.

46. Plomp T. Educational design research: An introduction. Educ. Des. Res.2013;204. http://international.slo.nl/publications/edr/%5Cnhttp://international.slo.nl/edr/

47. Mayer RE. Using multimedia for e-learning. J Comput Assist Learn 2017;33(5):403–23.

48. Willems J, Farley H, Freund K, Britten D, Tickner S, Tucker S, et al. Digital Equity. ASCILITE Publ 2018;565–7.

49. Treviranus J. Learning differences & digital equity in the classroom. 2018. https://api.semanticscholar.org/CorpusID:149426715

50. Kalogiannakis M, Zourmpakis AI, Menšíková M, Lategan F, Patelarou A, Patelarou E, et al. Use of an e-toolkit in the development of digital competencies in Weeks of International Teaching. Adv Mob Learn Educ Res 2023;3(1):702–17.

51. D. Villaroza R, C. Villaroza R, D. Canoy JC, N. Macalong ER, A. Coronado W. Exploring the Impact of GeoGebra on Mathematical Proficiency and Inductive Reasoning Ability in Geometry Students of MSU N – Integrated Developmental School. Int J Sci Manag Stud 2023;128–42.

52. Negara HRP, Wahyudin, Nurlaelah E, Herman T. Improving Students' Mathematical Reasoning Abilities Through Social Cognitive Learning Using GeoGebra. Int J Emerg Technol Learn 2022;17(18):118–35.

53. Yerizon, Arnellis, Tasman F, Widjaja W. Enhancing Junior High School Students' Reasoning of Linear Equations Using GeoGebra Software. Int J Interact Mob Technol 2023;17(18):16–32.

54. Diener MJ. Cohen's d. 2010. https://api.semanticscholar.org/CorpusID:118784905

55. Tran C, Smith B, Buschkuehl M. Support of mathematical thinking through embodied cognition: Nondigital and digital approaches. Cogn Res Princ Implic 2017;2(1):16.

56. Nurulaini Jaafar, Siti Rohani Mohd Nor, Siti Mariam Norrulashikin, Nur Arina Bazilah Kamisan, Ahmad Qushairi Mohamad. Increase Students' Understanding of Mathematics Learning Using the Technology-Based Learning. IInternational J Adv Res Futur Ready Learn Educ 2022;28(1):24–9.

57. Serin H. Technology-integrated Mathematics Education: A Facilitating Factor to Enrich Learning. Int J Learn Dev 2017;7(4):60.

58. Serin H. The Integration of Technological Devices in Mathematics Education: A Literature Review. Int J Soc Sci Educ Stud 2023;10(3).

59. Clements DH, Battista MT. Geometry and spatial reasoning.. 1992. https://api.semanticscholar.org/CorpusID:208102237

60. Mayer RE. The Cambridge Handbook of Multimedia Learning. Cambridge University Press; 2020.

61. van Dijk AM, Lazonder AW. Scaffolding students' use of learner-generated content in a technology-enhanced inquiry learning environment. Interact Learn Environ 2016;24(1):194–204.

62. Fraenkel J, Wallen N, Hyun H. How to Design and Evaluate Research in Education. 2011.

63. Koehler MJ, Mishra P, Akcaoğlu M, Rosenberg JM. The Technological Pedagogical Content Knowledge Framework for Teachers and Teacher Educators. 2013. https://api.semanticscholar.org/CorpusID:14595097

64. Hidayati A, Zuhdi S, Resti M, Azaria TT, Andary L. Use of Canva in Primary School Education: A Qualitative Study of The Use, Advantages and Disadvantages of Canva. ICEETE Conf Ser 2024;2(1):322–6.

65. Zainal Abidin SR, Jalaluddin NF, Ismail NZ, Zainal MA. The Efficacy of Canva as a Digital Tool for Enhancing Student Learning in Multimedia Interactive Subjects. Int J e-Learning High Educ 2025;20(2):1–18.

66. Abdullah IH, Wahyudi D, Syam Tonra W, Syam Tonra W, Hasbi M. DEVELOPMENT OF DIGITAL TEACHING MATERIALS BASED ON DIFFERENTIATED LEARNING USING CANVA FOR MATHEMATICS SUBJECTS. EduMatSains J Pendidikan, Mat dan Sains 2025;9(2):244–55.

67. Polya G. How to Solve it. Princeton University Press; 1973.

68. Lithner J. Principles for designing mathematical tasks that enhance imitative and creative reasoning. ZDM 2017;49(6):937–49.

69. Morales Méndez G, Lozano Avilés AB. Augmented reality and GeoGebra 3D for improving spatial intelligence in teaching volumetric geometry. Rev Educ a Distancia 2025;25(82).

70. Yerizon Y, Dwina F, Tajudin NM. Improving Students' Spatial Ability with GeoGebra Software. Univers J Educ Res 2021;9(1):129–35.

71. Mayer RE. Multimedia Learning. Cambridge University Press; 2009.

72. Nelson-Fromm T. Creating Better Teaching Tools Through Examining Teachers' Understanding of Data Representations. In: IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC). IEEE; 2021. page 1–2.

73. Pedersen MK, Bach CC, Gregersen RM, Højsted IH, Jankvist UT. Mathematical Representation Competency in Relation to Use of Digital Technology and Task Design—A Literature Review. Mathematics 2021;9(4):444.

74. Setiyani S, Putri DP, Ferdianto F, Fauji SH. DESIGNING A DIGITAL TEACHING MODULE BASED ON MATHEMATICAL COMMUNICATION IN RELATION AND FUNCTION. J Math Educ 2020;11(2):223–36.

75. Lehane P. Use without training: A case study of evidence-based software design for intuitive use. Hum Technol 2019;100–35.

76. Bass M, Movahed SH. To What Extent can 'Bring Your Own Device' be an Enabler to Widening Participation in Higher Education for the Socially Disadvantaged? J Perspect Appl Acad Pract 2018;6(1):3–11.

77. Baccaglini-Frank A. To tell a story, you need a protagonist: how dynamic interactive mediators can fulfill this role and foster explorative participation to mathematical discourse. Educ Stud Math 2021;106(2):291–312.

78. Rabani S, Khairat A, Guilin X, Jiao D. The Role Of Technology In Indonesian Education At Present. J Comput Sci Adv 2023;1(2):85–91.

79. Tomić MK, Aberšek B, Pesek I. GeoGebra as a spatial skills training tool among science, technology engineering and mathematics students. Comput Appl Eng Educ 2019;27(6):1506–17.

80. Kim KM, Md-Ali R. Geogebra: Towards realizing 21st century learning in mathematics education. Malaysian J Learn Instr 2017;

81. Martín-Gutiérrez J, Gil FA, Contero M, Saorín JL. Dynamic three-dimensional illustrator for teaching descriptive geometry and training visualisation skills. Comput Appl Eng Educ 2013;21(1):8–25.

82. Stylianides GJ. Reasoning-and-proving in school mathematics textbooks. Math Think Learn 2009;11(4):258–88.

83. Jeannotte D, Kieran C. A conceptual model of mathematical reasoning for school mathematics. Educ Stud Math 2017;96(1):1–16.

84. Fried L, Konza D. Using Self-Determination Theory to Investigate Student Engagement in the Classroom. Int J Pedagog Curric 2013;19(2):27–40.

85. Ikahihifo TB. Self-Determination Theory and Student Emotional Engagement in Higher Education. 2019. https://api.semanticscholar.org/CorpusID:181365266

FINANCING

This research was funded by Universitas Negeri Malang through the Indonesian Research Collaboration Program 2024, based on the Notice of Acceptance No. 5.4.97/UN32/KP/2024 and Research Funding Agreement No. 5.4.76/UN32.14.1/LT/2024.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Data curation: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Formal analysis: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Research: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Methodology: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Drafting - original draft: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.
Writing - proofreading and editing: Lathiful Anwar, Yuhana Faradila Muzam Roudloh, Cholis Sa'dijah, Yerizon, Maiyastri.