

## DESIGNING A NO-CODE ASSESSMENT TO ANALYSE STUDENTS' MATHEMATICAL LITERACY IN SPATIAL GEOMETRY

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### Abstract

This study was designed to examine a no-code assessment tool to analyse and strengthen junior high students' mathematical literacy in spatial geometry. A design-based research approach guided cycles of needs analysis, tool design, classroom iteration, and evaluation with purposively selected participants. Post-implementation assessments indicated marked gains in literacy performance, alongside richer engagement with modeling, representation, and interpretation. The tool elevates learning because interactive tasks, visual supports, and real-time feedback reduce cognitive load, connect problems to meaningful contexts, and scaffold metacognition. The work demonstrates a practical pathway for educators to build adaptable, low-barrier assessments that integrate into diverse devices and settings, and it outlines design principles that can be replicated and extended to other mathematical topics and question types. It also reports feasibility feedback from media, content, and language experts, and summarizes iterative refinements that improved accessibility, clarity, and problem structure across devices and classroom practice evidence.

Keywords: AppSheet, Design, Design-based research, Mathematical literacy, Spatial geometry.

## **1. Introduction**

Mathematical literacy is recognized as a crucial competency in 21st-century education [1, 2]. It encompasses not only the ability to perform calculations but also the capacity to comprehend, analyse, and solve real-world problems using mathematical reasoning [3]. However, empirical evidence indicates that the mathematical literacy of Indonesian students remains relatively low, as reflected in Programme for international student assessment (PISA) scores and national assessments [4, 5]. According to organisation for economic co-operation and development (OECD) data from the 2018 PISA cycle, Indonesia ranked 73rd, placing seventh from the bottom, with an average score of 379. This was a decline from its 62nd position in 2015, particularly among junior high school students [6-8].

Based on this data, PISA findings consistently concluded that Indonesian junior high school students exhibit weak mathematical literacy [9]. The PISA assessment measures mathematical literacy through problem-solving tasks embedded in real-life contexts [10]. Analysis of Indonesian students' responses reveals that most only reach level 2 out of six proficiency levels, suggesting significant challenges in applying mathematics beyond procedural operations [11, 12]. This underperformance underscores a gap between academic instruction and functional mathematical understanding.

The OECD defines mathematical literacy as the ability to formulate, apply, and interpret mathematics across a variety of contexts [13]. This includes conceptual understanding, procedural application, and logical reasoning to address practical issues [14]. Mathematical literacy involves more than executing algorithms; it requires foundational knowledge, competence, and confidence to apply mathematics in everyday situations [15, 16]. A mathematically literate individual can make estimates, interpret data, solve contextual problems, and communicate ideas using numerical, graphical, or spatial forms [17].

In line with this perspective, mathematical literacy is viewed as the capacity to use mathematical thinking to confront real-life challenges [18]. It involves not only cognitive abilities like problem-solving, reasoning, and explanation but also the development of mindsets grounded in mathematical concepts and facts [19-21]. The concept emphasizes the formulation and evaluation of mathematical ideas through functional reasoning and structured thinking [22, 23].

To strengthen students' mathematical literacy, various learning models have been developed and implemented by educators [24, 25]. These models are often rooted in constructivist theory, which emphasizes multisensory engagement in the learning process. By activating multiple senses, students are able to internalize concepts more effectively [26]. Constructivist models are student-centered, encouraging active participation and deeper conceptual understanding.

In the digital era, technology-enhanced assessments have also played a pivotal role in improving mathematical literacy. Numerous studies report positive outcomes from using technology-based tasks and learning media [27-31]. Digital platforms (including games, Android apps, and web tools) have been used to facilitate learning, particularly in geometry, using tools such as GeoGebra [32]. One emerging solution involves leveraging mobile-based platforms like AppSheet to develop problem-based instruments that assess mathematical literacy [33].

AppSheet is a no-code platform that enables educators to design question-based applications accessible via mobile devices, particularly Android, without requiring programming skills [34]. Its ease of use and accessibility make it a valuable resource for both teachers and students. Several studies have demonstrated AppSheet's effectiveness in supporting the development of cognitive, psychomotor, and affective domains in education [35-39].

The purpose of this study is to describe how the AppSheet platform was designed to explore students' mathematical literacy skills using a design-based research (DBR) approach, involving four stages: analysis, design, iteration, and evaluation. This research offers three main novelties: (i) the design of an assessment instrument using AppSheet, (ii) a focus on geometric shapes as the content domain, and (iii) the use of AppSheet to diagnose students' mathematical literacy abilities in spatial geometry contexts.

## **2. Literature Review**

### **2.1. AppSheet platform**

AppSheet is a no-code application development platform provided by Google that enables users to create mobile and web-based applications without requiring knowledge of programming or computer science [40]. The platform supports integration with tools such as Google Sheets, Excel, and SQL databases, making it an efficient medium for developing digital forms, workflows, and data collection systems [41, 42]. Due to its flexibility and adaptability, AppSheet empowers users without technical backgrounds (particularly educators and those in the educational technology sector) to build customized digital solutions that address specific pedagogical and administrative needs [43, 44].

Figure 1 presents a data flow diagram that illustrates the operational structure of AppSheet. It outlines the interaction among three core components: the Cloud Provider, the AppSheet Server, and the mobile device interface. In this architecture, the Cloud Provider and AppSheet Server function as the backend infrastructure, while the mobile interface represents the frontend accessible by users. The data exchange is illustrated through four stages: "1. Read", "2. Read", "3. Write", and "4. Write", emphasizing AppSheet's real-time cloud capabilities for both retrieving and updating data.

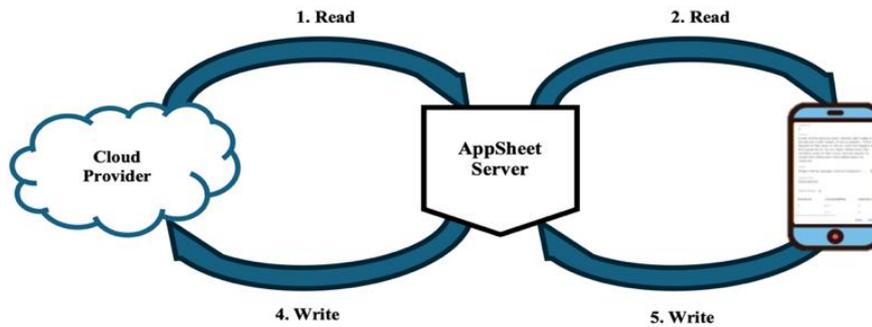
From an educational technology perspective, AppSheet offers a viable solution for developing adaptive and integrated learning applications [45, 46]. Its web-based accessibility allows both teachers and students to interact with content regardless of time and location, eliminating geographical limitations [47, 48]. As depicted in Figure 1, the platform also supports dynamic content delivery, such as image rendering and search functions, based on server-side configurations. This capacity enables the creation of responsive and interactive learning environments tailored to user needs [49, 50].

### **2.2. Mathematical literacy abilities**

Mathematical literacy is defined as an individual's capacity to formulate, apply, and interpret mathematical concepts, procedures, and tools across diverse real-life contexts [51]. This competency extends beyond computational fluency, encompassing logical and systematic reasoning, mathematical modeling, and

quantitative analysis [52, 53]. Theoretically, mathematical literacy integrates three principal dimensions:

- (i) mathematical content such as algebra, geometry, and statistics.
- (ii) cognitive processes, including problem formulation, strategic application, and result interpretation; and
- (iii) situational contexts, which may be personal, social, or scientific [54].



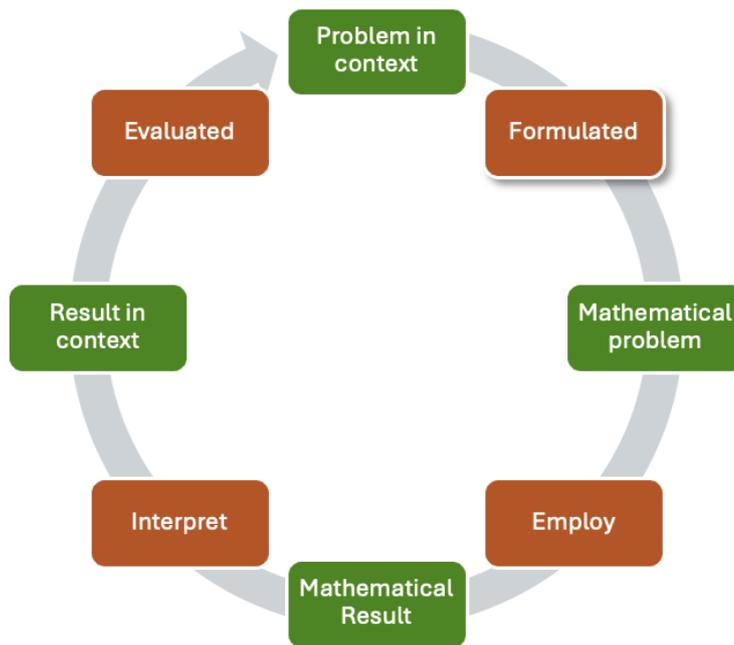
**Fig. 1. Flowchart about AppSheet.**

This framework reflects the principles of situated cognition, which posit that mathematical understanding is contextually grounded and constructed through active engagement in meaningful activities [55, 56]. Structurally, mathematical literacy follows a cyclical problem-solving model consisting of six key stages:

- (i) identifying a real-world problem,
- (ii) formulating a mathematical representation,
- (iii) solving it using algorithmic or heuristic strategies,
- (iv) validating the solution based on logical and empirical criteria,
- (v) interpreting the mathematical result within the original context, and
- (vi) evaluating its relevance and implications for the real-world situation [57].

This process requires metacognitive skills to monitor and regulate cognitive strategies during problem-solving [58]. From a Vygotskian perspective, mathematical literacy is cultivated through socio-cultural scaffolding, where learners engage with semiotic tools (such as symbols, diagrams, and visual representations) as cognitive mediators [59, 60].

Figure 2 illustrates this mathematical literacy cycle, beginning with the "Problem in context" where the learner identifies a real-life situation requiring mathematical intervention [61]. The issue is then reformulated into a solvable mathematical problem, which is addressed to obtain a mathematical result ("Employ"). This result is interpreted in relation to the original context and further evaluated for accuracy and relevance. The cyclical nature of this model highlights the iterative process of reflection, refinement, and reinterpretation, indicating that mathematical literacy involves nonlinear and dynamic problem-solving pathways [62].



**Fig. 2. Mathematical literacy for assessment and analytical framework.**

### 2.3. Geometric shapes in mathematics

Geometric shapes are among the most fundamental elements in mathematics. A geometric shape is defined as a collection of points in space that possesses specific metric and topological properties [63, 64]. Traditionally, these shapes are classified into two categories: two-dimensional (2D) shapes (such as triangles, squares, circles, and polygons) and three-dimensional (3D) shapes (such as cubes, spheres, pyramids, and prisms) [65, 66]. The theoretical basis of geometric shapes is rooted in Euclidean geometry, where core attributes such as length, angle, circumference, and area are defined based on postulates like the parallel line postulate [67-69]. In contrast, recent advances in mathematics have expanded to include non-Euclidean geometries, where properties are determined by the curvature of space, as demonstrated in the works of Lobachevsky and Riemann [70-72].

Geometric shapes can be analysed using distinguishing mathematical features [73, 74]. In 2D geometry, characteristics such as the number of edges, types of angles, and symmetries are critical [75]. For example, triangles may be classified based on their internal angles (acute, right, obtuse) or their side lengths (equilateral, isosceles, scalene) [76]. In contrast, 3D shapes are evaluated based on volume, surface area, and spatial configuration or nets [77]. Analytical representations of shapes are often expressed using coordinate systems (Cartesian, polar, or spherical) and defined through algebraic equations [78, 79].

The application of geometric shapes extends far beyond theoretical mathematics. In physics, engineering, architecture, and computer graphics,

geometric principles underpin essential technologies and models [80]. For instance, differential geometry informs models of curved surfaces and manifolds, such as those in general relativity [81]. In computational geometry, algorithms like Voronoi diagrams and Delaunay triangulations are employed for spatial optimization and network mapping [82, 83]. Moreover, group theory (particularly symmetry groups) helps explain geometric transformations like reflection, rotation, dilation, and translation, all of which are foundational in fields such as crystallography and fractal geometry [84]. Thus, geometric shapes are not only integral to pure mathematics but also catalyze innovations in science and technology [85-87].

Table 1 displays eight fundamental geometric shapes alongside their respective area and perimeter formulas. A conceptual grasp of these properties is essential for mathematical literacy and finds direct relevance in architectural modeling, engineering design, and scientific analysis [88]. The table provides formulas that clarify the mathematical relationships between parameters like side lengths, radii, and angles. Understanding these relationships helps bridge foundational geometric concepts with advanced scientific applications [89].

**Table 1. Geometric shape formula.**

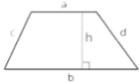
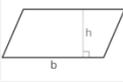
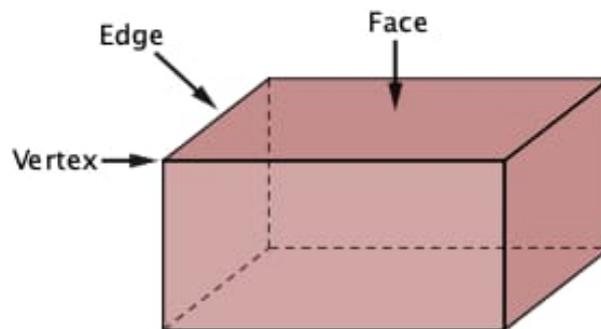
Shape	Name	Formulas
<b>A</b> 	Square	A polygon with all equal sides $Area = a \times a = a^2$ Perimeter $a+a+a+a = 4a$
<b>B</b> 	Rectangle	A polygon with parallel sides equal $Area = l \times w$ Perimeter = $2w + 2l$
<b>C</b> 	Triangle	A polygon with three edges and three angles $Area = \frac{1}{2}bh$ Perimeter = $a+b+c$
<b>D</b> 	Circle	All points at an equal distance from a center $Area = \pi r^2$ Perimeter = $2\pi r$
<b>E</b> 	Trapezoid	A polygon which has two parallel sides $Area = \frac{1}{2}(a + b)h$ Perimeter = $a+b+a+b$
<b>F</b> 	Parallelogram	A polygon with opposite sides parallel & equal $Area = bh$ Perimeter = $2(a+b)$
	Sector of a circle	A part of a circle has two radii and an arc $Area = (\theta \div 360)\pi r^2$ Perimeter = $2r+(\theta \div 360 \times 2\pi r)$

Figure 3 illustrates the decomposition of a rectangular prism into its fundamental components: flat surfaces (faces), line segments connecting the surfaces (edges), and points where edges meet (vertices). The image shows a purple rectangular face as one of the six identical surfaces that form the prism, while the transparent blue overlays offer a complete visual of the 3D form [90]. The labeling highlights: (i) the straight edges where two surfaces meet, (ii) the vertices where three or more edges converge, and (iii) the planar faces that define the prism's boundaries [91]. When counted, the prism contains 12 edges, 8 vertices, and 6 faces values that align with Euler's polyhedral formula:  $F + V - E = 2$  [92]. Beyond the identification of parts, this simple box exemplifies foundational 3D mathematical concepts applicable to various domains (from the crystalline structures in materials science to rendering techniques in computer graphics). The organization of points, lines, and surfaces adheres to geometric principles that underpin advanced spatial reasoning and structural design in mathematics, engineering, and computational disciplines [93].



**Fig. 3. Basic components for rectangular prism.**

Table 2 systematically outlines the topological attributes of various polyhedral forms and serves as empirical evidence supporting Euler's formula, ( $F + V - E = 2$ ), where  $F$  denotes the number of faces,  $V$  is the number of vertices, and  $E$  is the number of edges [94]. For instance, a cuboid (one of the simplest polyhedra) has 6 faces, 8 vertices, and 12 edges, yielding ( $6 + 8 - 12 = 2$ ), in accordance with the Euler characteristic. Pyramidal shapes consistently follow this topological rule: a triangular pyramid presents (4, 4, 6), a square pyramid (5, 5, 8), a rectangular pyramid (5, 5, 8), a pentagonal pyramid (6, 6, 10), and a hexagonal pyramid (7, 7, 12). Similarly, prism structures exhibit more complex configurations yet continue to uphold the same invariant: triangular prism (5, 6, 9), square prism (6, 8, 12), cube (6, 8, 12), pentagonal prism (7, 10, 15), octagonal prism (10, 16, 24), and heptagonal prism (9, 14, 21).

These data confirm that despite increasing geometric complexity, the Euler characteristic remains consistent across diverse families of polyhedra. The invariant relationship illustrates how the structural interplay between faces, vertices, and edges encapsulates deep combinatorial properties, underscoring the formula's relevance in algebraic topology [95, 96]. By verifying the formula across basic platonic solids and higher-order pyramids and prisms, this dataset not only affirms mathematical theory but also enhances conceptual understanding of 3D spatial structures in mathematics education.

**Table 2. The number of edges, faces, and vertices in a 3D geometric shape.**

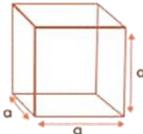
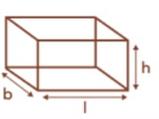
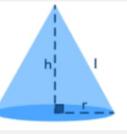
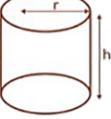
No.	Solid	Shape of Solid	Number of faces F	Number of Vertices V	Number of edges E	F + V	E + 2
A	Cuboid		6	8	12	14	14
B	Triangular Pyramid		4	4	6	8	8
C	Square Pyramid		5	5	8	10	10
D	Rectangular Pyramid		5	5	8	10	10
E	Pentagonal Pyramid		6	6	10	12	12
F	Hexagonal Pyramid		7	7	12	14	14
G	Triangular Prism		5	6	9	11	11
H	Square Prism		6	8	12	14	14
I	Cube		6	8	12	14	14
J	Pentagonal Prism		7	10	15	17	17
K	Octagonal Prism		10	16	24	26	26
L	Heptagonal Prism		9	14	21	23	23

Table 3 provides a comparative visualization of five geometric solids, accompanied by the respective quantitative formulas that define their volume and surface area. Understanding these three-dimensional properties is not only foundational in Euclidean geometry but also forms the basis for a wide array of applications in physics, engineering, and computational science [97, 98]. Each geometric form ranging from the symmetrical cube to the curved cone exhibits distinct structural features. These characteristics are reflected in mathematical relationships involving linear dimensions

(e.g., height, radius, side length), which are used to determine spatial capacity (volume) and surface boundaries (surface area) [99].

Analysing the formulas for each solid reveals deeper geometric principles while simultaneously demonstrating the practical relevance of these calculations in real-world problem-solving. For example, the accurate determination of surface area and volume is essential in optimizing material use in architecture and manufacturing, as well as in simulating three-dimensional objects in digital modeling environments [100]. Thus, the mathematical understanding of volume and surface area extends beyond theoretical constructs to become instrumental in applied sciences and technology.

**Table 3. Volume and surface area in 3D geometric shapes.**

No.	Shape	Volume	Surface Area
a	<p>Cube</p> 	Volume = $a^3$	Surface Area = $6a^2$
b	<p>Rectangular Prism of Cuboid</p> 	Volume = $l \times b \times h$	Surface Area = $2(l \times b + b \times h + l \times h)$
c	<p>Sphere</p> 	Volume = $\frac{4}{3} \pi r^3$	Curved Surface Area = $4\pi r^2$
d	<p>Cone</p> 	Volume = $\frac{1}{3} \pi r^2 h$	Curved Surface Area = $\pi r l$ Total Surface Area = $\pi r l + \pi r^2 = \pi r(l + r)$ $(l = \sqrt{h^2 + r^2})$
e	<p>Cylinder</p> 	Volume = $\pi r^2 h$	Curved Surface Area = $2\pi r h$ Total Surface Area = $2\pi r h + 2\pi r^2 = 2\pi r(h + r)$

Explanation in Table 3 is as follows:

- (i) Number a shows a cube is a regular polyhedron with 6 identical square faces, 12 edges of equal length, and 8 vertices. Each dimension has the same length ( $a$ ), so its volume is expressed as the cube of the edge length ( $V=a^3$ ), reflecting the principle of spatial measurement in three orthogonal dimensions. The total surface area ( $6a^2$ ) is obtained by summing the areas of all its square faces. The cube exhibits octahedral symmetry and serves as the basis for the concept of unit cells in crystallography [101].
- (ii) Number b shows that a rectangular prism is a generalization of the cube with edges of different lengths ( $l, b, h$ ). Its volume ( $V=l \times b \times h$ ) represents the scalar product of three-dimensional vectors, while its surface area  $2(lb+bh+lh)$  accounts for the sum of the areas of its three pairs of rectangular faces. This shape is widely used in architecture and structural design due to its proportional flexibility [102].
- (iii) Number c shows that a sphere is defined as the set of points at a constant distance ( $r$ ) from its center. Its volume ( $\frac{4}{3}\pi r^3$ ) is derived from the integral of spherical shells, while its surface area ( $4\pi r^2$ ) shows a quadratic dependence on the radius. The sphere has constant positive Gaussian curvature and maximizes volume for a given surface area (the isoperimetric principle) [103].
- (iv) Number d shows cone consists of a circular base with radius  $r$  and a lateral surface with a slant height. Its volume ( $\frac{1}{3}\pi r^2 h$ ). Cones model fluid flow dynamics and pressure distribution phenomena [104].
- (v) Number e shows cylinder has two parallel circular bases and a rolled rectangular lateral surface. Its volume ( $\pi r^2 h$ ) is the product of the base area and height, while its total surface area ( $2\pi r(h+r)$ ) includes the lateral area ( $2\pi r h$ ) and both bases. Cylinders form the basis for analysing axial stress in mechanical engineering and thermodynamics [105].

### 3. Method

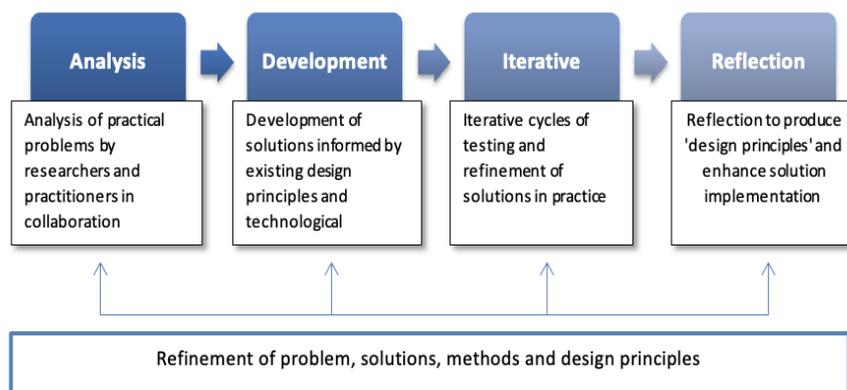
Figure 4 illustrates the research framework, which adopts a DBR methodology to guide the development and validation of the AppSheet-based application. This methodology was selected due to its iterative and context-sensitive structure, which integrates cycles of design, implementation, evaluation, and refinement within authentic educational settings. DBR enables researchers to bridge theoretical constructs with practical classroom needs by directly involving students and educators in the design process. Consequently, the resulting educational tool is not only empirically tested but also pedagogically meaningful and responsive to real learning environments.

The flowchart outlines a four-phase DBR framework designed to address instructional challenges in geometry learning. In the Analysis Phase, researchers and practitioners collaboratively diagnose problems (particularly gaps in students' ability to contextualize geometric concepts) using insights from classroom observations and literature reviews. The Development Phase focuses on designing the AppSheet interactive tool, incorporating Van Hiele's cognitive theory and technological innovations such as 3D visualizations to promote mathematical literacy.

The Iterative Phase involves cyclical testing and refinement through classroom implementation. Data from student interactions, literacy assessments,

and teacher feedback are analysed to improve the application's effectiveness—for example, by adjusting problem complexity or integrating augmented reality features. The final Reflection Phase synthesizes findings into generalizable design principles, such as the importance of real-world contextualization and scaffolding in enhancing spatial reasoning.

Throughout all phases, the process of Refinement, depicted by a two-way arrow in the flowchart, allows dynamic revision of the problem definition, design components, and implementation strategies. This adaptability ensures continuous alignment with evolving pedagogical needs. Ultimately, the DBR approach employed in this study not only results in a validated technology-enhanced learning tool but also offers theoretical contributions to the field. Specifically, it is in the form of design principles for literacy-based STEM interventions that emphasize iterative development, contextual relevance, and practitioner collaboration.



**Fig. 4. Phases of design-based research.**

The participants in this study consisted of 39 students from class VIII B of a junior high school in Bandung, Indonesia. The sample was selected using a purposive sampling technique based on their accessibility, representativeness of the target user group, and relevance to the research focus on spatial geometry. This context provided a practical and authentic setting for testing the implementation of the AppSheet-based assessment tool in a real classroom environment.

Data collection employed multiple instruments to ensure triangulation and comprehensive evaluation of both the learning tool and student outcomes:

- (i) **Needs Analysis through Literature Review:** A preliminary investigation was conducted based on existing research findings that consistently reported a deficiency in students' mathematical literacy (particularly in spatial geometry). This analysis justified the necessity of developing targeted assessment media aimed at improving students' conceptual understanding and literacy in geometry.
- (ii) **Expert Validation and Limited Trial:** The developed AppSheet application was subjected to expert validation to assess its content quality, media functionality, and language clarity. Experts in mathematics education, digital learning media, and English language reviewed the product, followed by a

limited-scale classroom trial to ensure its usability, accuracy, and alignment with learning objectives.

- (iii) Pretest and Posttest Competency Assessment: To evaluate the effectiveness of the application, students were administered a pretest and a posttest focusing on mathematical literacy in spatial geometry. The assessments measured changes in students' ability to understand, apply, and interpret mathematical concepts in real-world contexts following the use of the application.

## 4. Results and Discussion

### 4.1. Analysis of the need to improve mathematical literacy

Table 4 presents a synthesis of previous research findings and bibliometric analyses that highlight persistent deficiencies in students' mathematical literacy particularly in relation to the integration of technology, assessment frameworks, and the use of tools such as AppSheet within spatial geometry learning contexts.

**Table 4. Previous research on mathematical literacy and the integration of technology, assessment, and spatial geometry.**

No.	Research Title	Ref.
1	Assessing tenth-grade students' mathematical literacy skills in solving PISA problems	[106]
2	Lower secondary students' encounters with mathematical literacy	[107]
3	Mathematics Literacy Task on Number Pattern Using Bengkulu Context for Junior High School Students	[108]
4	Online Learning: How Does It Impact on Students' Mathematical Literacy in Elementary School?	[109]
5	Minimum competency assessment to measure mathematical literacy of junior high school students	[110]
6	Evolving three decades of geometry learning strategies: A combination of bibliometric analysis and systematic review	[111]

A review of recent studies reveals several interrelated factors contributing to students' low mathematical literacy. Students in Grade 10 have been found to struggle with solving PISA tasks involving mathematical modeling and quantitative reasoning, indicating a limited capacity to apply mathematical knowledge in real-world situations [106]. This is supported by findings that junior high school students frequently fail to connect mathematical concepts with everyday contexts, reflecting a shallow level of conceptual understanding [107].

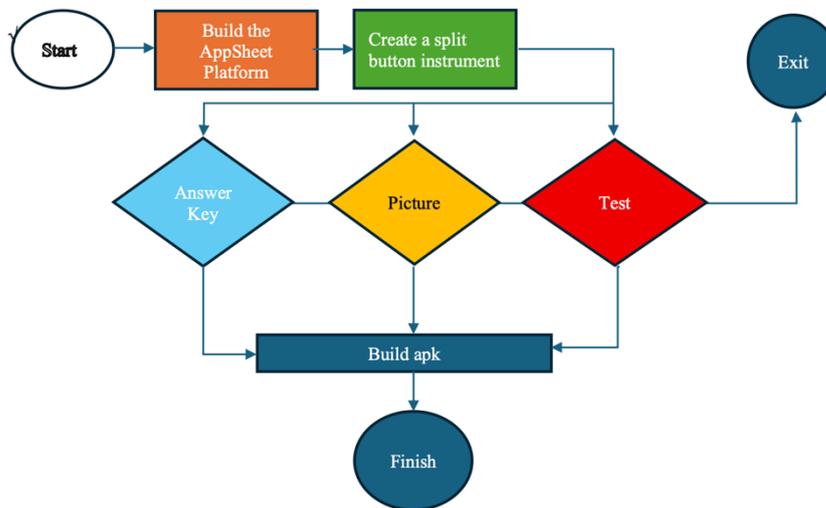
Although contextualizing problems using local culture such as those in the Bengkulu region can increase student engagement, challenges in abstract reasoning and cognitive flexibility persist [108]. Moreover, online learning conditions have further worsened the situation, as limited teacher-student interaction significantly hampers the development of mathematical literacy, particularly at the elementary level [109]. Minimum competency assessments have also revealed a notable gap between procedural fluency and the ability to apply mathematics in unfamiliar or complex contexts [110].

From a broader historical lens, the last three decades of instructional practices in geometry have not effectively addressed these challenges, pointing to persistent inadequacies in how geometry is taught to develop mathematical literacy [111]. These findings collectively suggest the need for a more comprehensive and integrated instructional approach (one that emphasizes conceptual understanding, real-world relevance, technological integration, and robust assessment design).

The implications of these studies are far-reaching, impacting not only classroom teaching strategies but also informing educational policy and professional development programs aimed at addressing mathematical literacy deficits systemically and sustainably.

#### 4.2. Design of AppSheet for assessment in spatial geometry on mathematical literacy

Figure 5 illustrates the flow diagram of the AppSheet platform designed specifically to assess and enhance students' mathematical literacy in spatial geometry. The flowchart demonstrates a structured development process that aligns technology integration with pedagogical objectives in mathematics education.



**Fig. 5. Flow chart of the appsheet application for mathematical literacy assessment.**

The process begins with the Start phase, initiating the construction of the AppSheet platform. This is followed by the development of a split-button navigation instrument, which allows users to interact with the application seamlessly. The workflow then branches into three essential components:

- (i) Answer Key provides structured support for problem-solving and helps students reflect on correct mathematical reasoning.
- (ii) Picture Integration incorporates visual elements such as geometric figures and contextual illustrations to reinforce spatial understanding.

- (iii) Test Module serves as the core assessment component, enabling students to engage in mathematical literacy tasks designed to evaluate their comprehension, reasoning, and application skills.

These elements converge at the Build APK stage, where the application is compiled into an executable mobile format, and the process concludes at the Finish phase. The split-button tool also features an Exit function, granting users flexibility and autonomy in their learning experience.

This design reflects a user-centered approach that embeds key mathematical literacy principles (namely, contextualized problem-solving, multimodal representation, and interactive learning). The iterative structure of the application allows for continuous refinement based on classroom implementation and learner feedback, ensuring pedagogical alignment and usability [112]. Moreover, the integration of visual, procedural, and evaluative features supports the creation of an engaging digital learning environment that strengthens conceptual understanding and spatial reasoning [113, 114].

### **4.3. Development and iterative improvement of the application**

Figure 6 presents the AppSheet-based application developed to assess and improve mathematical literacy skills in spatial geometry, particularly focusing on three-dimensional figures such as cuboids. The final product, accessible via Android devices, is structured as an interactive platform and can be previewed through the link: <https://www.appsheet.com/start/baf15173-7035-4f57-86ad-0ed4f5cd6cb6>.

Figures 6(a) and 6(b) showcase a key interactive feature of the application, designed to support the development of students' spatial reasoning through applied mathematical tasks. The example provided presents a problem involving a cuboid labeled (ABCD.EFGH), with clearly defined dimensions: length ( $AB = 8$ ) m, width ( $BC = 6$ ) m, and height ( $CG = 5$ ) m. The problem is divided into two parts:

- (i) Task A: Calculating the area of the diagonal plane (ACGE), visually emphasized in red.
- (ii) Task B: Identifying the spatial diagonals of the cuboid.

To support comprehension, dynamic image integration is used through an external link, allowing students to interact with labeled vertices (A–H) and visual representations of geometric dimensions. The interface features a multiple-choice format for answer input (e.g., selecting "D" or "H"), while system fields such as ComputedKey and Question ID facilitate automated scoring through algorithmic logic. In addition, a relational database of answers (including fields like Related Answers and Answer ID) enables detailed error tracking and supports the generation of varied question items through updatable image links.

From a pedagogical perspective, this iterative design supports abstract reasoning by connecting symbolic problems with concrete visual representations. It emphasizes contextualized problem-solving through realistic geometry applications (e.g., calculating surface areas of diagonal planes) and enhances student feedback loops via real-time computerized assessment [115, 116]. As such, the AppSheet platform extends beyond conventional practice tools by fostering deeper conceptual understanding and enabling iterative cognitive development in mathematical literacy [117].

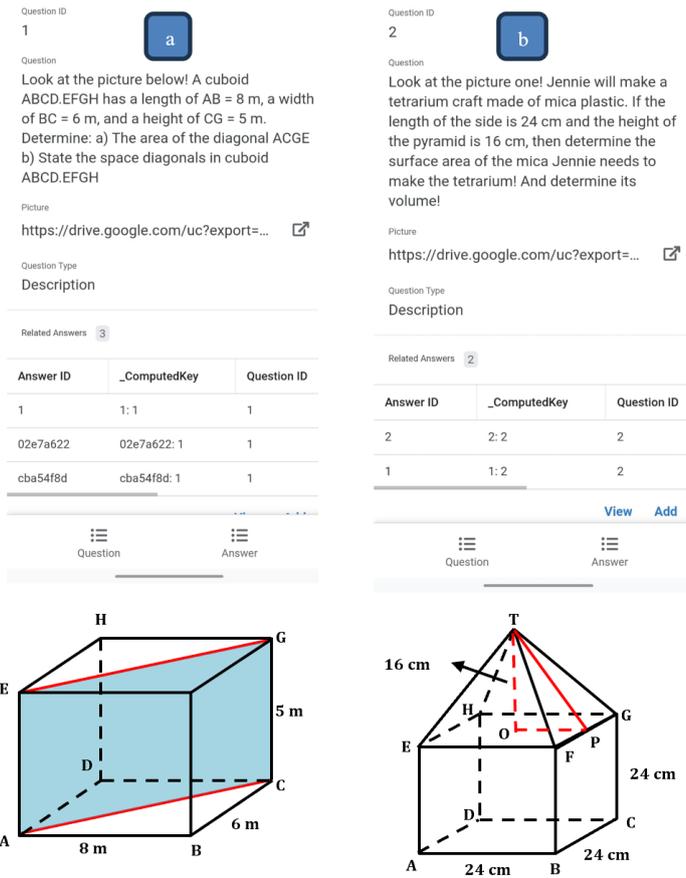


Fig. 6. AppSheet spatial geometric: a) test number 1, b) test number 2.

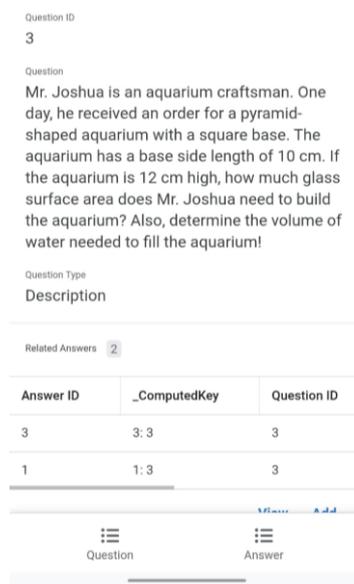
Figure 7 illustrates the spatial geometry test feature embedded in the AppSheet platform, specifically designed to train students' ability to calculate surface area and volume in the context of square-based pyramids. This feature represents a contextualized problem-solving task that challenges students to apply geometric concepts to a real-world scenario involving the construction of a pyramid-shaped aquarium.

In the task, students are provided with specific parameters: a square base with a side length of 10 cm and a vertical height of 12 cm. Based on this information, they are required to determine two key quantities: (i) the surface area of the glass needed to construct the aquarium and (ii) the volume of water required to fill it. Although the application does not present a visual illustration, the textual description substitutes for imagery and guides students in mentally visualizing the geometric shape and structure.

This assessment feature reinforces mathematical literacy by integrating three critical components. First, it links abstract geometric concepts (such as surface area and volume) to tangible applications, enhancing the relevance of mathematics in daily life. Second, it provides practice in procedural fluency, requiring accurate use of formulas in solving measurement-related problems. Third, it promotes spatial

reasoning through descriptive cues that prompt students to mentally construct and manipulate geometric forms.

By incorporating contextual problems, guided parameters, and real-time scoring mechanisms, AppSheet functions as an adaptive assessment tool. It supports differentiated learning while maintaining conceptual depth, positioning itself as a practical solution for strengthening students' understanding of spatial geometry through inquiry-based and literacy-oriented assessment strategies.



**Fig. 7. Test number 3 about appsheet test spatial geometric.**

In the development process, this Appsheet has been validated by three experts, namely media experts, material experts, and language experts. There are several notes on the validation process that were made changes to the product before revision, including: i) media expert notes: the application must be set to be usable on the lowest and highest types of Android so that it can accommodate all types of Android owned by students, by setting the supported type of Android and making this Appsheet platform multi-functional which can be accessed in the form of applications on Android as well as web-based so that on PCs and other devices it is still used, in the first trial the image of the question did not appear so it is recommended that if there are obstacles in coding embed pictures directly, it is more efficient to enter the gdrive link to save and display the question image; ii) material expert notes, create questions mathematically by providing initial values as keys to solving problems in the use of mathematical structures and appropriate values to make it easier for students to solve problems in the questions, in addition, make sure the image of the geometric shape is clear accompanied by appropriate values and units; and iii) language expert notes, try to use clear and targeted language, not long-winded, choose the words used to explain the meaning and purpose of the question, and change the language of the question to English.

Based on the validator's notes, improvements were made, and trials were conducted with ten users until the developed AppSheet could be read and used as

intended. The AppSheet is currently limited to just three questions, so further development is needed to make it more comprehensive.

The development and validation process of the AppSheet platform involved rigorous evaluation by three distinct experts: media, material, and language specialists to ensure its pedagogical and technical efficacy. Media experts emphasized the necessity of cross-platform compatibility, recommending optimization for both low and high-end Android devices and dual functionality (app and web-based) to maximize accessibility. A critical technical adjustment was the shift from embedded image coding to Google Drive links to resolve display issues, enhancing reliability [118, 119].

Material experts underscored the importance of structured problem-solving by mandating initial values and clear geometric diagrams with precise units, ensuring mathematical clarity and reducing cognitive load for students. Language experts advocated for concise, unambiguous question phrasing and a transition to English to standardize communication and align with global educational standards. Following iterative revisions informed by these validators, user trials with ten participants confirmed the platform's usability and alignment with learning objectives. However, the current limitation to three questions highlights the need for further expansion to achieve comprehensive coverage, suggesting future iterations should prioritize scalability and enriched content diversity to fully realize the tool's potential in enhancing spatial geometry literacy.

#### 4.4. Reflection of the application

The implementation of the AppSheet platform yielded statistically significant improvements in students' mathematical literacy, as evidenced by the results of the Wilcoxon signed-rank test. The test revealed a significance value of ( $p < 0.001$ ), with a large effect size reflected by the notable disparity between positive ranks ( $M = 58.42$ ) and negative ranks ( $M = 39.70$ ). Given that ( $p < \alpha = 0.05$ ), the findings confirm the effectiveness of the AppSheet application in enhancing conceptual mastery of spatial geometry, particularly in guiding students' progression from lower to higher proficiency levels (Smith et al., 2022).

Before the intervention, the distribution of students across achievement categories was predominantly in the "Very Poor" (D) group at 51%, followed by "Poor" (C) at 26%, "Good" (B) at 13%, and only 10% in the "Very Good" (A) category. After using the AppSheet platform, a significant upward shift was observed, with many students moving into higher performance tiers and an outcome consistent with the positive rank dominance observed in the Wilcoxon analysis.

These results highlight the pedagogical potential of interactive digital tools in outperforming traditional teaching methods, particularly in developing spatial reasoning and problem-solving skills essential to geometry education [120-122]. The shift in students' mathematical competence also aligns with Vygotskian sociocultural theory, which posits that scaffolded environments (such as those offered by AppSheet) facilitate cognitive development by providing adaptive feedback and contextualized tasks [123-125].

Despite these promising outcomes, the limited sample size ( $N = 39$ ) presents a constraint to generalizability. Therefore, future studies should replicate this research with larger and more diverse populations. Furthermore, incorporating

machine learning features to personalize learning pathways could increase effectiveness, while expanding the complexity of assessment tasks would allow for measurement of higher-order thinking skills [126, 127]. These refinements, in line with recommendations from the National Council of Teachers of Mathematics, would further establish AppSheet as a transformative tool in STEM education [128, 129]. Finally, this study adds new information regarding mathematics education (see Table 5).

**Table 5. Previous studies regarding mathematics education.**

No.	Title	Ref.
1	Structural equation modelling of factors influencing confidence in mathematics	[130]
2	Factors that affect the performance of selected high school students from the third district of Albay in International Mathematics Competitions	[131]
3	Efforts to increase the interest of junior high school students in mathematics lessons using the TikTok learning tool	[132]
4	Math readiness and its effect on the online academic performance of science, technology, engineering, and mathematics students	[133]
5	Assessing teachers' formative evaluation strategy as related to senior secondary school students' achievement in mathematics	[134]
6	Exploration of the effect of the scaffolding instructional strategy on pupils' academic performance in mathematics	[135]
7	Effect of peer-tutoring strategy on senior secondary school students' achievement in mathematics	[136]
8	Exploring effective differentiated instruction in the teaching and learning of mathematics	[137]
9	Impact of single parenting on academic performance of junior secondary school students in mathematics	[138]
10	Perceptions of senior high school science, technology, engineering, and mathematics (STEM) students toward STEM and non-STEM courses: A comparative qualitative study	[139]

**5. Conclusion**

This study developed and validated an AppSheet-based digital application designed to assess and enhance students' mathematical literacy in the context of spatial geometry. Using a DBR approach, the application was constructed through iterative cycles involving analysis, development, implementation, and reflection within authentic classroom settings. The results demonstrated a statistically significant improvement in students' performance, particularly in conceptual understanding, spatial reasoning, and the application of geometric formulas in real-world contexts.

The reasoning behind these improvements lies in the AppSheet platform's ability to contextualize mathematical tasks, integrate visual and interactive components, and provide automated feedback, which collectively support metacognitive development and learner engagement. The tool proved effective in bridging the gap between abstract mathematical knowledge and practical application. Given its adaptability and accessibility, the AppSheet platform represents a promising model for technology-based assessment tools in STEM education. Future research is encouraged to expand its application across diverse topics and integrate intelligent features for personalized learning, thereby reinforcing its role in advancing mathematical literacy at scale.

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