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ORIGINAL ARTICLE

Developing Learners' Mathematical Problem-Solving Competence in Teaching Visual Geometry to Grade 7 Students Using the Dynamic Geometry Software GeoGebra

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ABSTRACT
In the 2018 Mathematics General Education Curriculum, Visual Geometry is expected to help lower secondary students develop spatial reasoning, mathematical representation, and problem-solving competence. However, the teaching of three-dimensional geometry often relies on static illustrations, which may limit students' opportunities to manipulate, explore, and verify geometric relationships. This article examines the pedagogical potential of GeoGebra 3D in supporting Grade 7 students' mathematical problem-solving competence in learning the topic of rectangular prisms and cubes. Using a pedagogical design-oriented analysis, the study proposes and analyzes a teaching procedure in which students observe dynamic 3D models, unfold rectangular prisms to construct the lateral surface area formula, and use unit cubes to conceptualize volume. The analysis is grounded in the 2018 Mathematics General Education Curriculum, theories of mathematical problem solving, scholarship on visual geometry and dynamic geometry environments. The proposed activities illustrate how GeoGebra 3D can support students in identifying problems, formulating conjectures, testing relationships, generalizing formulas, and applying knowledge to geometric situations. The article contributes a theoretically grounded instructional illustration for teaching Visual Geometry with digital tools, while highlighting the need for further empirical research to examine its effectiveness in classroom contexts.

1. INTRODUCTION

In the context of competency-based education, mathematics teaching is expected not only to transmit knowledge but also to develop students' mathematical thinking, reasoning, modeling, communication, and problem-solving competence. In Vietnam, the 2018 Mathematics General Education Curriculum (MGEC) identifies mathematical problem-solving competence and the ability to use mathematical tools and learning media as important components of students' mathematical competence (Ministry of Education and Training, 2018). Within this curriculum orientation, Visual Geometry at the lower secondary level provides an important foundation, helping students observe, describe, imagine, and represent geometric objects in relation to real-world situations.

Geometry plays a central role in developing students' visualization, spatial reasoning, conjecturing, logical argumentation, and problem-solving skills. Previous studies have shown that geometry learning can be significantly supported when students are given opportunities to manipulate representations, explore relationships, and connect visual experiences with mathematical reasoning (Jablonski & Ludwig, 2023; Jones & Tzekaki, 2016; Sunzuma, 2023). However, in many classrooms, three-dimensional geometric objects are still mainly represented through static drawings or textbook illustrations. Though such representations may help students recognize shapes, they often limit opportunities to observe transformations, test hypotheses, and understand how formulas are constructed.

The topic of rectangular prisms and cubes in Grade 7 mathematics curriculum is particularly suitable for developing students' spatial reasoning and mathematical problem-solving competence. In this topic, students are required not only to identify geometric elements such as faces, edges, and vertices, but also to analyze the relationships among dimensions, lateral surface area, and volume. In the 2018 MGEC, students are expected to recognize three-dimensional shapes such as rectangular prisms and cubes and calculate their lateral surface areas and volumes (Ministry of Education and Training, 2018). Therefore, teaching this topic should move beyond formula memorization to creating opportunities for students to explore how formulas emerge from geometric structures.

Dynamic geometry software, particularly GeoGebra 3D, provides a learning environment in which students can observe, manipulate, measure, unfold, rotate, and verify geometric objects. Research on technology integration in geometry education indicates that digital tools can support visualization, experimentation, modeling, and the solving of routine and non-routine mathematical problems (Sunzuma, 2023). GeoGebra has also been reported to support students' visual reasoning, conjecture formation, and exploration of geometric relationships (Dockendorff & Solar, 2018; Muslim et al., 2023). More broadly, digital tools in mathematics education can function not only as presentation tools but also as cognitive tools that support conceptual development and mathematical reasoning (Clark-Wilson et al., 2020; Filiz, 2025).

Despite the growing body of research on technology-enhanced geometry learning, several gaps remain. First, many studies have focused on the general benefits of digital technologies in geometry education, while fewer studies have analyzed how GeoGebra 3D-supported activities can be structured to develop mathematical problem-solving competence in lower secondary education. Second, existing studies often emphasize visualization and conceptual understanding, but less attention has been paid to the learning process through which students identify problems, formulate conjectures, verify geometric relationships, and generalize formulas. Third, in the context of the Vietnamese 2018 Mathematics Curriculum, there remains a need for pedagogically grounded instructional illustrations that connect Visual Geometry, dynamic geometry environments, and competency-based learning outcomes.

Therefore, this article aims to analyze the theoretical and pedagogical foundations for developing students' mathematical problem-solving competence in teaching Visual Geometry in Grade 7 with the support of GeoGebra 3D. Specifically, the article focuses on the concepts of rectangular prisms and cubes and proposes an instructional procedure that helps students construct the lateral surface area and volume formulas through dynamic visualization, manipulation, verification, and generalization.

2. LITERATURE REVIEW

2.1. Mathematical problem-solving competence

Mathematical problem-solving competence is a key objective of competency-based mathematics education. In the Vietnamese 2018 MGEC, mathematical competence comprises mathematical thinking and reasoning, mathematical modeling, mathematical problem solving, mathematical communication, and the ability to use mathematical tools and learning media (Ministry of Education and Training, 2018). Within this framework, mathematical problem-solving competence refers to students' ability to identify mathematical problems, propose and implement solution strategies, use mathematical knowledge and skills appropriately, and evaluate or generalize the obtained results.

This orientation is consistent with classical and contemporary perspectives on mathematical problem solving. Polya (1957) described problem solving as a process involving four stages: understanding the problem, devising a plan, carrying out the plan, and looking back. These stages emphasize that mathematical learning should not be reduced to applying formulas mechanically, but should involve identifying the structure of a problem, selecting suitable strategies, implementing them, and reflecting on the solution. Schoenfeld (2016) further argued that mathematical problem solving requires not only content knowledge but also strategic competence, metacognitive monitoring, and the ability to make sense of mathematical situations.

In the context of Vietnamese mathematics education, Nguyen and Le (2021) emphasized that problem-based teaching situations can facilitate the development of students' mathematical problem-solving competence by engaging learners in identifying problems, proposing solution strategies, presenting solutions, and extending or generalizing results. Similarly, Nguyen et al. (2024) highlighted the importance of real-world mathematical problems in helping students transform practical situations into mathematical tasks and apply appropriate mathematical knowledge to solve them. These perspectives provide a basis for analyzing how students' problem-solving competence can be developed through teaching Visual Geometry.

For this study, mathematical problem-solving competence is operationalized through four observable indicators:

(1) identifying and formulating geometric problems;

(2) proposing exploratory strategies or hypotheses;

(3) using mathematical tools, representations, and reasoning to verify relationships;

(4) evaluating, generalizing, and applying results to related situations.

These indicators are used as the analytical lens for examining the proposed GeoGebra 3D-supported teaching sequence.

2.2. Visual Geometry and spatial reasoning

Visual Geometry plays an important role in lower secondary mathematics because it helps students develop spatial reasoning, geometric representation, and the ability to connect visual objects with mathematical concepts. Research on the teaching and learning of geometry has shown that geometry is not merely a domain of shapes and formulas, but a field that supports visualization, reasoning, conjecturing, argumentation, and problem solving (Jablonski & Ludwig, 2023; Jones & Tzekaki, 2016; Sunzuma, 2023). In particular, learning three-dimensional geometry requires students to coordinate multiple representations, imagine objects from different perspectives, and understand relationships among faces, edges, vertices, dimensions, surface area, and volume.

However, students often encounter difficulties when three-dimensional objects are represented only through static textbook figures. Static drawings may support initial recognition, but they do not always allow students to observe transformations, manipulate objects, or verify geometric relationships dynamically. This limitation is especially evident in the teaching of rectangular prisms and cubes, where students need to understand how lateral surface area can be constructed from unfolded lateral faces and how volume can be conceptualized through the filling of space by unit cubes.

The 2018 MGEC requires Grade 7 students to recognize three-dimensional shapes such as rectangular prisms and cubes and calculate their lateral surface areas and volumes (Ministry of Education and Training, 2018). Therefore, the teaching of this topic should help students move from visual perception to mathematical generalization. Instead of presenting formulas as ready-made knowledge, instruction should create opportunities for students to observe, manipulate, conjecture, verify, and construct formulas based on geometric structures.

2.3. GeoGebra 3D as a dynamic geometry environment

Dynamic geometry environments provide opportunities for students to interact with mathematical objects in ways that are difficult to achieve through static representations. GeoGebra 3D allows students to rotate, unfold, measure, drag sliders, observe changes in parameters, and visualize geometric relationships in real time. In this sense, GeoGebra 3D can function not only as a presentation tool but also as a cognitive tool that supports exploration, reasoning, and knowledge construction.

Research on technology integration in geometry education indicates that digital tools can support visualization, experimentation, modeling, and the solving of routine and non-routine mathematical problems (Sunzuma, 2023). GeoGebra, in particular, has been widely used in mathematics education because it provides multiple representations and supports learners in exploring geometric structures dynamically (Muslim et al., 2023). Dockendorff and Solar (2018) showed that GeoGebra can support visualization, conjecture formation, and exploratory reasoning in mathematics learning. From a broader perspective, Clark-Wilson et al. (2020) noted that the educational value of digital technology depends not only on the tool itself but also on the design of mathematical tasks and the teacher's orchestration of classroom activity. Filiz (2025) also emphasized that digital tools in mathematics education can contribute to conceptual development by helping learners interact with abstract mathematical objects.

In Vietnam, Nguyen et al. (2023) showed that GeoGebra can support students in using mathematical tools and learning media, especially in spatial geometry learning. The dynamic manipulation of geometric objects enables students to rotate figures, observe spatial relationships, make predictions, and verify conjectures. These affordances are closely aligned with the development of mathematical problem-solving competence because students are required to observe a situation, identify a problem, select a strategy, test relationships, and generalize findings.

For the topic of rectangular prisms and cubes, GeoGebra 3D can support two key conceptual constructions. First, the unfolding function helps students observe that the lateral surface of a rectangular prism consists of four rectangles whose dimensions are related to the perimeter of the base and the height of the prism. This supports the construction of the formula ($S_{\{lat\}} = 2(a + b)c$). Second, the use of unit cubes helps students conceptualize volume as the number of unit cubes filling the three-dimensional space, thereby supporting the construction of the formula ($V = a \times b \times c$). Through these activities, students are not merely taught the formulas but are guided to construct them through visual exploration and mathematical reasoning.

2.4. Analytical framework for GeoGebra 3D-supported problem-solving activities

Based on the above theoretical foundations, this study proposes an analytical framework that connects GeoGebra 3D-supported Visual Geometry activities with the development of mathematical problem-solving competence. The framework is grounded in four foundations: the 2018 MGEC, Polya's problem-solving process, research on visual geometry, and literature on dynamic geometry environments.

The proposed framework consists of four interrelated phases:

First, students identify and formulate geometric problems. In the learning situation, students are asked to consider practical or geometric questions such as how much wrapping material is needed for a rectangular prism-shaped box or how the amount of material changes when one dimension changes. This stage corresponds to problem identification and activates students' prior knowledge.

Second, students explore and formulate hypotheses through dynamic manipulation. By using GeoGebra 3D sliders, rotation tools, and unfolding functions, students observe how changes in dimensions affect the shape, lateral faces, and spatial structure of the rectangular prism. This supports hypothesis formation and strategic exploration.

Third, students verify relationships and construct formulas. Through the unfolded model, students identify the four lateral rectangles and reason that their total area can be expressed as ($S_{\{lat\}} = 2(a + b)c$). Using the unit-cube model, students observe that volume can be determined by counting the number of unit cubes in one layer and then multiplying by the number of layers, leading to ($V = a \times b \times c$). This stage links visual evidence with mathematical reasoning.

Fourth, students evaluate, generalize, and apply the results. Students compare the formulas for rectangular prisms and cubes, recognize the cube as a special case when ($a = b = c$), and apply the formulas to related geometric or real-life situations. This process supports reflection, generalization, and transfer of knowledge.

The analytical framework is summarized as follows:

Table 1. Analytical framework connecting GeoGebra 3D-supported activities and mathematical problem-solving competence

GeoGebra 3D-supported activity	Mathematical action	Indicator of problem-solving competence
Observing a rectangular prism or cube in a dynamic 3D environment	Identifying geometric elements and relationships	Identifying and formulating the problem
Manipulating dimensions using sliders and rotating the model	Exploring changes and proposing conjectures	Proposing strategies or hypotheses
Unfolding the prism and analyzing lateral faces	Verifying relationships and constructing the lateral surface area formula	Using representations and reasoning to solve the problem
Filling the prism with unit cubes	Conceptualizing volume through spatial structure	Verifying and generalizing mathematical relationships

Comparing rectangular prisms and cubes; solving related tasks	Applying and reflecting on the formulas	Evaluating, generalizing, and applying results

This framework provides the theoretical basis for the instructional illustration presented in the following sections. It also underscores the need for a clear connection between exploratory activities using GeoGebra 3D and the development of students' mathematical problem-solving competence.

3. MATERIALS AND METHODS

3.1. Research approach

This study employs a pedagogical design-oriented analytical approach. The purpose of the study was not to report a full-scale experimental intervention, but to develop and analyze an illustrative teaching sequence for the topic of rectangular prisms and cubes in Grade 7 Visual Geometry with the support of GeoGebra 3D. This orientation was chosen because the study focuses on investigating how dynamic geometry activities can be structured to support students' mathematical problem-solving competence, rather than measuring learning outcomes through pre-test and post-test data.

The design of the teaching sequence was grounded in four sources: the requirements of the 2018 MGEC, theories of mathematical problem solving, research on Visual Geometry and spatial reasoning, and studies on dynamic geometry environments. In particular, the 2018 MGEC provides the curricular basis for selecting the topic of rectangular prisms and cubes, while Polya's problem-solving process and Schoenfeld's perspective on mathematical thinking provide theoretical foundations for analyzing students' problem-solving actions (Ministry of Education and Training, 2018; Polya, 1957; Schoenfeld, 2016). Studies on GeoGebra and technology-enhanced geometry learning provide the basis for designing dynamic visualization and exploration activities (Dockendorff & Solar, 2018; Muslim et al., 2023; Sunzuma, 2023).

Therefore, the study should be viewed as a theoretically grounded instructional design and analysis. The proposed activities are intended to illustrate how GeoGebra 3D may support students in observing, manipulating, conjecturing, verifying, and generalizing geometric relationships. The analysis does not claim empirical effectiveness, but provides a structured pedagogical framework that can serve as a basis for future classroom implementation and empirical validation.

3.2. Teaching content and digital materials

The selected teaching content was the topic of rectangular prisms and cubes in Grade 7 Mathematics. This topic was chosen for three reasons. First, it is directly related to the Visual Geometry strand in the lower secondary mathematics curriculum. Second, it requires students to connect three-dimensional objects with two-dimensional representations, especially when constructing the lateral surface area formula through the unfolding of a prism. Third, it provides an appropriate context for developing mathematical problem-solving competence because students need to identify relationships among dimensions, surface area, and volume, and then generalize formulas drawing on these relationships.

The digital learning materials were developed using GeoGebra 3D. The GeoGebra models included three main components:

1. A dynamic rectangular prism model with adjustable dimensions (a), (b), and (c), allowing students to observe changes in the shape and size of the prism.
2. An unfolding model of the rectangular prism, allowing students to observe how the four lateral faces form a strip of rectangles whose total area corresponds to the lateral surface area.
3. A unit-cube filling model, allowing students to conceptualize volume as the number of unit cubes needed to fill the rectangular prism.

These models were designed to help students move from visual observation to mathematical reasoning. The dynamic prism model supports the identification of geometric elements and relationships; the unfolding model supports the construction of the lateral surface area formula; and the unit-cube model supports the construction of the volume formula.

The GeoGebra 3D models used in this instructional illustration were designed to support students' exploration of rectangular prisms and cubes through dynamic manipulation, unfolding, and unit-cube filling. The main model is available at GeoGebra (Duong & Hoa, 2026): https://www.geogebra.org/m/ppquacmv#material/gjktq28f. In the analysis, the models are treated as digital learning materials that provide opportunities for students to observe geometric structures, formulate conjectures, verify relationships, and generalize formulas.

3.3. Pedagogical design procedure

Based on the analytical framework presented in Section 2.4, the teaching procedure was designed around four problem-solving phases: problem identification, dynamic exploration, mathematical explanation, and application/reflection. To avoid presenting formulas as ready-made knowledge, each phase was organized through a specific GeoGebra 3D-supported task.

In the problem-identification phase, students are introduced to practical or geometric situations, such as determining the amount of material needed to cover the lateral surface of a rectangular-prism-shaped box or finding the number of unit cubes needed to fill a prism. In the exploration phase, students manipulate the dimensions of the rectangular prism, rotate the model, unfold the lateral faces, and observe the unit-cube filling process. In the explanation phase, students use their observations to construct the formulas for lateral surface area and volume. In the application/reflection phase, students solve related tasks, compare rectangular prisms and cubes, and explain why the formulas are reasonable.

Thus, Section 3.3 describes how the theoretical framework was translated into a concrete instructional procedure, while the detailed analysis of students' possible mathematical actions is presented in the Results and Discussion section.

3.4. Analytical criteria

To analyze the pedagogical value of the proposed teaching sequence, this study used a set of criteria based on the indicators of mathematical problem-solving competence. These criteria were not used to measure students' actual achievement, but to examine whether each teaching activity provides opportunities for students to engage in problem-solving processes.

The analytical criteria are presented in Table 2.

Table 2. Analytical criteria for GeoGebra 3D-supported problem-solving activities

Indicator of mathematical problem-solving competence	Description in the context of Visual Geometry	Evidence expected from the teaching activity
Identifying and formulating the problem	Students recognize what needs to be found, such as lateral surface area or volume, and relate the question to the structure of a rectangular prism or cube.	Students identify the relevant dimensions, faces, layers, or unit cubes involved in the task.
Proposing strategies or hypotheses	Students suggest ways to explore the problem using GeoGebra 3D, such as unfolding the prism, changing dimensions, or filling the prism with unit cubes.	Students make predictions about how surface area or volume changes when dimensions change.
Verifying relationships through representations and reasoning	Students use visual models, measurements, and geometric reasoning to test their hypotheses.	Students explain the relationship between the unfolded lateral faces and ($S_{\{lat\}} = 2(a + b)c$), or between unit cubes and ($V = a \times b \times c$).
Generalizing and applying results	Students express the observed relationships as formulas and apply them to related cases.	Students generalize from rectangular prisms to cubes and use

	formulas in new geometric or practical situations.

This analytical framework helps examine the role of each GeoGebra 3D activity in supporting the development of mathematical problem-solving competence. For example, the unfolding activity is analyzed not only as a visualization task but also as an opportunity for students to identify geometric relationships, test hypotheses, and construct the lateral surface area formula. Similarly, the unit-cube filling activity is analyzed as a way to help students conceptualize volume through spatial structuring and generalization.

3.5. Scope and limitations of the method

Since this study is based on pedagogical design and analytical interpretation, it has several limitations. First, it does not provide quantitative evidence such as pre-test and post-test scores. Second, it does not report systematic classroom observation data, interviews, or student worksheets from a full-scale implementation. Third, the proposed teaching sequence needs to be further tested with actual Grade 7 students in different classroom contexts.

However, the absence of a full-scale empirical intervention does not reduce the value of the study as an instructional design analysis. The contribution of the study lies in the development of a theoretically grounded teaching sequence and an analytical framework that connects GeoGebra 3D-supported activities with specific indicators of mathematical problem-solving competence. This provides a basis for future empirical studies that may examine the effectiveness of the proposed approach using classroom data, student products, interviews, or quantitative assessment instruments.

4. RESULTS AND DISCUSSION

4.1. Constructing the lateral surface area formula through unfolding

The first instructional focus of the proposed teaching procedure is the construction of the lateral surface area formula for a rectangular prism. Instead of presenting the formula directly, the GeoGebra 3D model allows students to observe the rectangular prism as a three-dimensional object, manipulate its dimensions, and unfold its lateral faces into a two-dimensional representation. This process is important because it helps students connect the spatial structure of the prism with the algebraic form of the formula.

At the beginning of the activity, students observe a rectangular prism with three adjustable dimensions: length (a), width (b), and height (c). Through rotation and visual inspection, students identify the faces, edges, and vertices of the prism. The teacher may pose guiding questions such as: “Which faces form the lateral surface of the prism?”, “How many lateral faces does the prism have?”, and “What are the dimensions of each lateral face?”. These questions help students formulate the mathematical problem: determining the total area of the lateral faces.

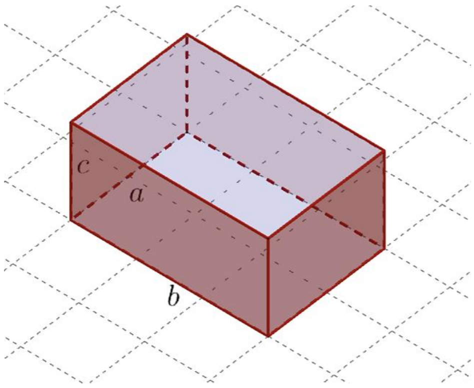

Figure 1. Dynamic GeoGebra 3D model of a rectangular prism with adjustable dimensions

The unfolding model then provides a visual basis for students to verify their conjectures. When the four lateral faces are unfolded, students can observe that they form a strip of four rectangles. Two of these rectangles have dimensions (a) and (c), while the other two have dimensions (b) and (c). Therefore, the total lateral surface area can be expressed as:

$$S_{\{lat\}} = ac + bc + ac + bc = 2ac + 2bc = 2(a + b)c$$

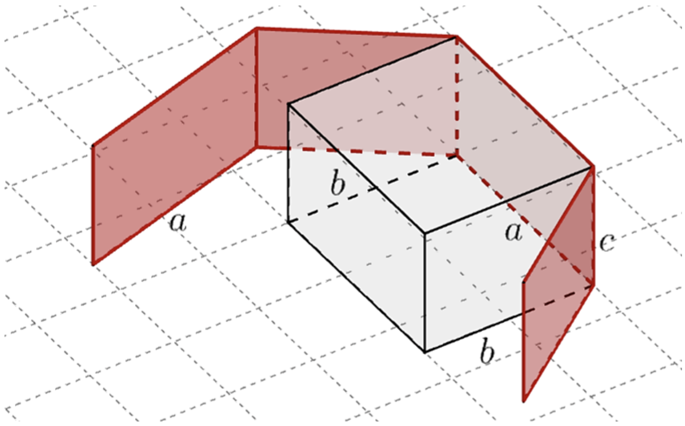

Figure 2. Process of unfolding of the lateral faces of a rectangular prism in GeoGebra 3D

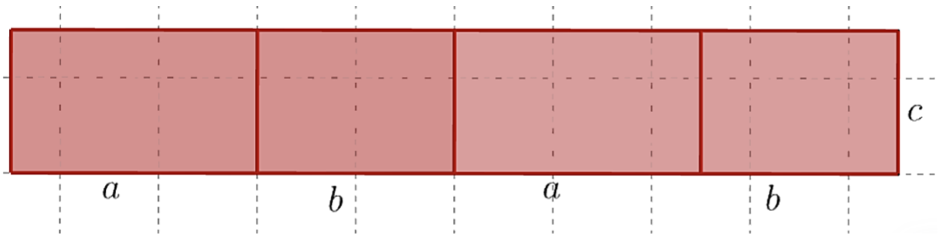

Figure 3. Two-dimensional representation of the unfolded lateral faces used to construct the lateral surface area formula

This construction helps students understand that the lateral surface area is not an independent formula to be memorized. Rather, it emerges from the structure of the rectangular prism. The expression (2(a+b)) can be interpreted as the perimeter of the base, while (c) represents the height of the prism. Thus, the formula can also be generalized as:

$$S_{\{lat\}} = C_{\{base\}} \times h$$

For the cube, students recognize that all dimensions are equal, namely $(a = b = c)$. Therefore, the lateral surface consists of four congruent square faces, and the formula becomes:

$$S_{\{lat\}} = 4a^2$$

Regarding mathematical problem-solving competence, this activity allows for several important processes. First, students identify the problem by recognizing that the lateral surface is composed of specific faces of the prism. Second, they propose a strategy by unfolding the three-dimensional figure into a two-dimensional representation. Third, they verify relationships among dimensions by examining the unfolded lateral faces. Finally, they generalize the observed relationship into a mathematical formula.

This analysis is consistent with previous research showing that dynamic geometry environments can support visualization, conjecture formation, and exploratory reasoning in mathematics learning (Dockendorff & Solar, 2018; Sunzuma, 2023). It also aligns with the view that geometry learning should help students connect visual experience with mathematical reasoning and generalization (Jones & Tzekaki, 2016; Jablonski & Ludwig, 2023). In this activity, GeoGebra 3D functions not merely as a visual aid, but as a cognitive environment that enables students to manipulate representations and construct mathematical meaning.

4.2. Constructing the volume formula through unit-cube filling

The second instructional focus is the construction of the volume formula for a rectangular prism. In traditional teaching, students are often given the formula $(V = a \times b \times c)$ and then asked to apply it to numerical exercises. However, such an approach may not help students understand why the formula represents the amount of space occupied by the prism. The GeoGebra 3D unit-cube model provides an alternative pathway by helping students conceptualize volume as the number of unit cubes required to fill the prism.

In this activity, students first observe an empty rectangular prism and a unit cube. The teacher guides students to consider the question: "How many unit cubes are needed to fill the prism completely?". Students then observe how unit cubes are arranged in rows, layers, and finally in the whole prism. This process helps students develop a spatial understanding of volume.

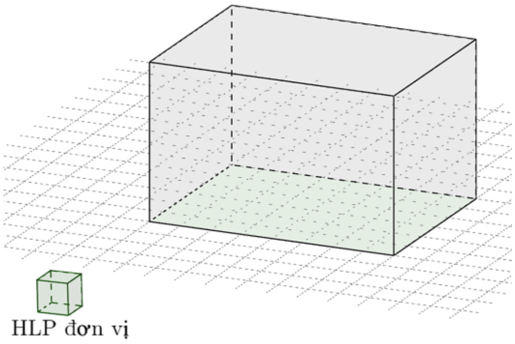

Figure 4. Unit-cube model used to conceptualize the volume of a rectangular prism

The first step is to form one row of unit cubes along one dimension of the base. If the length of the prism is (a), then one row contains (a) unit cubes. The next step is to complete one layer on the base. If the width is (b), then one layer contains: $a \times b$ unit cubes. Finally, if the height of the prism is (c), then the prism consists of (c) such layers. Therefore, the total number of unit cubes needed to fill the prism is:

$$V = (a \times b) \times c = a \times b \times c$$

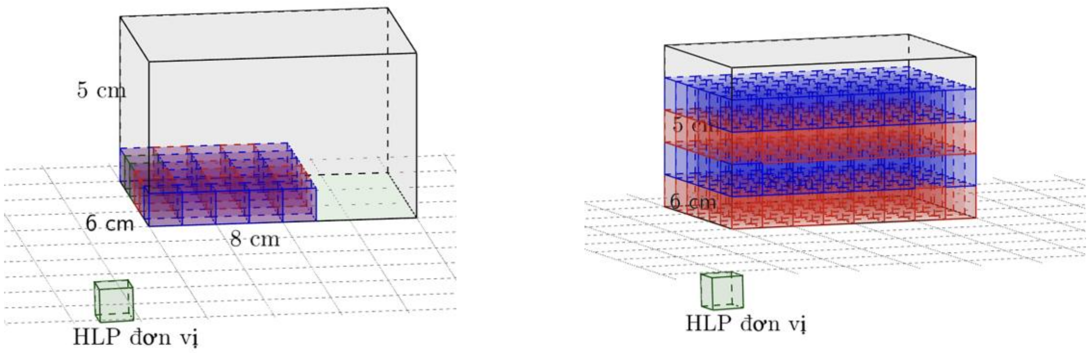

Figure 5. Process of filling the rectangular prism with unit cubes: from one layer to the completed solid

This construction allows students to see volume as a multiplicative structure rather than a formula stated in advance. The formula is built from spatial organization: number of cubes in one row, number of rows in one layer, and number of layers in the prism. When $(a = b = c)$, students recognize the cube as a special case, leading to:

$$V = a^3$$

Concerning problem-solving competence, the unit-cube filling activity is meaningful because it provides opportunities for students to connect observation, counting, spatial structuring, and algebraic generalization. Students are not only asked to calculate volume, but also to explain why the formula works. They may test different values of (a), (b), and (c) using sliders and observe how the number of unit cubes changes. This supports hypothesis testing and verification, which are important components of mathematical problem solving.

The pedagogical value of this activity is supported by research on digital tools in mathematics education. Dynamic digital environments can help students interact with mathematical objects, observe changes, and develop conceptual understanding through manipulation and exploration (Clark-Wilson et al., 2020; Filiz, 2025). In geometry learning, such environments are particularly useful because they make spatial relationships visible and manipulable (Sunzuma, 2023). In this analysis, the GeoGebra 3D unit-cube model is interpreted as supporting students' movement from intuitive spatial perception to formal mathematical reasoning.

4.3. GeoGebra 3D-supported activities and indicators of mathematical problem-solving competence

The proposed teaching procedure illustrates how GeoGebra 3D-supported activities can be connected with specific indicators of mathematical problem-solving competence. The analysis highlights that each activity is associated with a particular mathematical action and a corresponding opportunity for competence development.

First, the initial observation of a rectangular prism or cube supports the identification and formulation of a problem. When students are asked how to determine the amount of wrapping material or how many unit cubes are needed to fill a box, they are required to interpret a geometric situation and identify the mathematical quantities involved. This corresponds to the first indicator of problem-solving competence: recognizing and formulating a mathematical problem.

Second, the manipulation of dimensions using sliders supports the formulation of hypotheses. Students can change (a), (b), and (c), observe the resulting changes in the prism, and predict how lateral surface area or volume may change. For example, students may conjecture that increasing the height affects the lateral surface area and the volume, but in different ways. Such activities help students move beyond passive observation and become active investigators of mathematical relationships.

Third, the unfolding model supports verification and reasoning. By transforming the prism into its lateral net, students can verify that the lateral surface consists of four rectangles and that the total area can be expressed as $(2(a+b)c)$. This activity provides visual evidence for algebraic reasoning and helps students justify the formula. It also supports the transition from geometric representation to symbolic expression.

Fourth, the unit-cube model supports spatial structuring and generalization. By observing how the prism is filled by unit cubes, students can reason that the volume is determined by the number of unit cubes in one layer multiplied by the number of layers. This helps students construct the formula $(V = a \times b \times c)$ and recognize $(V = a^3)$ as the special case for a cube.

Fifth, application and reflection tasks support evaluation and transfer. After constructing the formulas, students may solve related problems involving rectangular boxes, packages, or containers. They may also compare rectangular prisms and cubes to identify invariant and variable relationships. These tasks help students evaluate the reasonableness of the formulas and apply them in new situations.

Overall, these activities show how GeoGebra 3D can support different phases of mathematical problem solving in learning rectangular prisms and cubes. Through observing, manipulating, unfolding, filling with unit cubes, and solving related tasks, students are provided with opportunities to identify geometric problems, formulate conjectures, verify relationships, generalize formulas, and apply the constructed knowledge in new situations.

However, the role of GeoGebra 3D should not be understood as automatically producing learning outcomes. Its pedagogical value depends on how the teacher designs tasks, poses questions, supports students' reasoning, and guides them from visual observation to mathematical generalization. This point has been emphasized by Clark-Wilson et al. (2020), who stated that the effectiveness of digital technology in mathematics education depends on the interaction among task design, classroom orchestration, and students' mathematical engagement.

4.4. Discussion

The analysis of the proposed teaching sequence yields three pedagogical findings that respond directly to the research gap identified in the Introduction.

Compared with previous studies that mainly emphasized the general role of digital tools in supporting visualization and exploration in geometry learning, this study makes a more specific pedagogical contribution by showing how GeoGebra 3D-supported activities can be structured around explicit indicators of mathematical problem-solving competence. In particular, the study does not only describe the use of GeoGebra 3D as a visualization tool, but also analyzes how students may progress through problem-identification, hypothesis formulation, verification, formula construction, generalization, and application. This is the main strength and distinctive contribution of the study: it connects dynamic 3D visualization, Grade 7 Visual Geometry content, and competency-based mathematics education within a coherent instructional and analytical framework.

First, GeoGebra 3D supports the transition from static visualization to dynamic exploration. In the topic of rectangular prisms and cubes, static textbook figures may help students recognize shapes, but they do not sufficiently show how lateral faces can be unfolded or how volume can be built from unit cubes. Through GeoGebra 3D, students can observe geometric objects from different perspectives, manipulate their dimensions, and explore relationships dynamically. This supports the development of spatial reasoning and geometric visualization, which are essential in learning three-dimensional geometry (Jablonski & Ludwig, 2023; Jones & Tzekaki, 2016).

Second, the proposed activities help students move from visual experience to formula construction. The lateral surface area formula is constructed by unfolding the prism and analyzing the four lateral rectangles. The volume formula is constructed by filling the prism with unit cubes and recognizing the multiplicative structure of rows, layers, and total space. These activities create a pathway from concrete visual representation to symbolic generalization. This is consistent with the argument that dynamic geometry environments can support conjecture formation, verification, and conceptual understanding (Dockendorff & Solar, 2018; Muslim et al., 2023).

Third, the teaching sequence provides a solution to connect Visual Geometry with mathematical problem-solving competence. Students are guided to identify problems, formulate hypotheses, verify relationships, generalize formulas, and apply knowledge to related situations. This aligns with the competency-based orientation of the 2018 MGEC, which emphasizes not only mathematical knowledge but also students' ability to solve problems and use mathematical tools and learning media (Ministry of Education and Training, 2018).

Nevertheless, this study has limitations. Since the analysis is based on pedagogical design rather than a full-scale classroom experiment, the findings should be interpreted as instructional and theoretical implications rather than empirical evidence of effectiveness. Future research should implement the proposed teaching sequence in actual classrooms, collect students' worksheets and products, conduct observations or interviews, and use pre-test and post-test data to examine changes in students' mathematical problem-solving competence.

5. CONCLUSION

This article analyzes the pedagogical potential of GeoGebra 3D in supporting the development of Grade 7 students' mathematical problem-solving competence through the topic of rectangular prisms and cubes. Based on the 2018 MGEC, theories of mathematical problem solving, research on Visual Geometry, and studies on dynamic geometry environments, the article proposed a teaching procedure in which students construct the lateral surface area and volume formulas through observation, manipulation, verification, and generalization.

The main contribution of this article lies in developing a theoretically grounded instructional illustration that connects GeoGebra 3D-supported Visual Geometry activities with mathematical problem-solving competence. Rather than presenting GeoGebra merely as a visualization tool, the article emphasizes its role as a dynamic learning environment that can support students' mathematical reasoning and formula construction. This contributes to the discussion on how digital tools can be integrated into competency-based mathematics teaching in the context of the Vietnamese 2018 Mathematics General Education Curriculum.

From a pedagogical perspective, the proposed teaching sequence suggests several implications for teachers. First, when teaching rectangular prisms and cubes, teachers should not introduce surface area and volume formulas as independent concepts. Instead, they should organize activities that allow students to explore how these formulas are constructed. Second, GeoGebra 3D should be complemented with guiding questions, discussion, and mathematical explanation. The tool itself does not automatically lead to learning; its effectiveness depends on task design, teacher orchestration, and students' active engagement. Third, teachers may combine digital models with physical models, worksheets, and practical problems to help students connect visual experience, mathematical reasoning, and real-life application.

However, this study has several limitations. It is based on pedagogical design and theoretical analysis rather than a full-scale empirical intervention. Therefore, the findings should be interpreted as instructional and theoretical implications, not as direct empirical evidence of effectiveness. The study does not include quantitative data, classroom observation records, interviews, or student products.

Future research should implement the proposed teaching sequence in actual Grade 7 classrooms, collect evidence from students' worksheets and learning products, and use qualitative or quantitative methods to examine how GeoGebra 3D affects students' mathematical problem-solving competence. Comparative studies between traditional instruction and GeoGebra 3D-supported instruction would also provide stronger evidence for evaluating the effectiveness of this approach.

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