ENHANCING STUDENTS' MATHEMATICAL COMPETENCE IN LEARNING SPATIAL GEOMETRY IN GRADE 11th THROUGH PRACTICAL AND EXPERIENTIAL ACTIVITIES

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Abstract

This study embarks on enriching 11th-grade students' mathematical competencies, particularly in spatial geometry, through experiential learning. Specifically, the study focused on the practical concepts of perpendicular and parallel relationships in space. Following the qualitative approach, we collected and analyzed the data of the students' behaviors observed within a teaching scenario, which was specifically designed for them to apply their knowledge to the task "determining the classroom's center". The scenario involved three phases: defining the "classroom center," problem-solving in the classroom, and group presentations analyzing each other's methods. The results showed that all student groups successfully solved the task, which was implemented in a serious way using their mathematical understanding in a real-life context. Thus, students enhanced their two mathematical competencies, including mathematical problem handling competency (posing and solving mathematical problems) and mathematical communication competency (communicating in, with and about mathematics). This study underscores the effectiveness of practical and experiential activities in enhancing mathematical competencies among high school students, specifically within spatial geometry. It highlights the benefits of applying mathematical concepts to practical situations, promoting more profound understanding and student engagement.

Keywords: *Mathematical competencies, practical and experiential activities, spatial geometry.*

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TĂNG CƯỜNG NĂNG LỰC TOÁN HỌC CỦA HỌC SINH TRONG HỌC TẬP HÌNH HỌC KHÔNG GIAN Ở LỚP 11 QUA CÁC HOẠT ĐỘNG THỰC HÀNH VÀ TRẢI NGHIỆM

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Tóm tắt

Nghiên cứu này đề cập đến việc nâng cao năng lực toán học của học sinh lớp 11 trong học hình học không gian qua học tập trải nghiệm. Cụ thể, nghiên cứu tập trung vào phương diện thực tiễn của các khái niệm song song và vuông góc trong không gian. Theo hướng tiếp cận định tính, chúng tôi thu thập và phân tích các dữ liệu quan sát được trên các hành vi của học sinh trong một tình huống dạy học được thiết kế để học sinh huy động các kiến thức hình học không gian cho nhiệm vụ "xác định tâm của lớp học". Tình huống gồm ba pha: định nghĩa "tâm lớp học", giải quyết vấn đề trong lớp học thực tế, thuyết trình nhóm và thảo luận các phương pháp khác nhau. Kết quả cho thấy tất cả các nhóm học sinh đều giải thành công nhiệm vụ được thực hiện một cách nghiêm túc bằng cách sử dụng hiểu biết toán học của các em vào bối cảnh thực tế đời sống. Từ đó, học sinh được nâng cao hai năng lực toán học, cụ thể là: năng lực giải toán và năng lực giao tiếp toán học. Nghiên cứu này nhấn mạnh tính hiệu quả các các hoạt động thực hành và trải nghiệm trong việc nâng cao năng lực toán học cho học sinh trung học, đặc biệt trong phạm vi hình học không gian. Nó cho thấy những lợi ích của việc áp dụng các kiến thức toán học vào các tình huống thực tế để thúc đẩy những hiểu biết sâu sắc hơn và khuyến khích sự tham gia của học sinh.

Từ khóa: *Năng lực toán học, hoạt động thực hành và trải nghiệm, hình học không gian.*

1. Introduction

Spatial geometry refers to the branch of mathematics concerned with understanding and working with three-dimensional objects in space. The abstraction of object dimensions leads to difficulties in visualization since these do not exist in reality (Nguyen & Dau, 2021). Spatial geometry often poses educational challenges due to the transition from two-dimensional representations to understanding three-dimensional structures. Geometry instruction should include teaching three-dimensional geometry and providing opportunities for students to use spatial abilities to solve problems (Güven & Kosa, 2008). A teaching style for spatial geometry might involve connecting it with plane geometry to solve problems (Dao & Luong, 2016).

Facing the challenges of integrating theory into practical applications of educational programs, on December 26, 2018, the Ministry of Education and Training issued the new General Education Program (Circular No. 32/2018/TT-BGDĐT). This program is aimed at "developing students' qualities and competencies; creating a learning and environment that supports their physical and mental development, becoming proactive, confident learners who know how to apply active learning methods to complete their fundamental knowledge and skills" (Ministry of Education and Training, 2018a, p. 4). "Practical and Experiential Activities" in Mathematics is a mandatory component from grades 1 to 12, occupying 7% of the entire curriculum, specifically 7% in Upper Secondary Education. The related contents involve applying mathematical knowledge to real-life and interdisciplinary topics, applying mathematical knowledge in Population Education, exploring some knowledge about finance, organizing extracurricular activities such as math clubs, learning projects, games, competitions, and organizing exchanges with excellent students within and between schools, with experts to understand more about the role of Mathematics in practice and various professions.

Under the critical objectives set by the 2018 General Education Program, "Experience" appears continuously in the program in three positions: general educational activities (as a subject that the program has referred to as experiential activities and career-oriented activities), activities associated with the subject (appearing integrated into lesson content), and experiential activities in teaching methods in lessons (Tang et al., 2021). In Vietnam, research works have followed the direction of experiential activities, which has brought many expected results. When teaching the concept of probability in grade 11, the experience of tossing cards, recording, and summarizing the results of the group and the class. The teacher illustrates the appearance of each side of the Rand program so that students are very confident that the frequency of each side appearing when tossed in large quantities will be close to 50%. Students are allowed to practice, experience, and apply the knowledge they have learned to reality. The experience-based teaching approach has helped students see that math has many applications in life (Nguyen et al., 2021). In another research work, when teaching the surface area of a cylinder, students directly manipulate the cylindrical cake box. The study results have shown that all student groups have approached the formula for calculating the surface area of the cylinder by flattening the cake shell and measuring the dimensions (Tang et al., 2021).

Currently, there are various bases for building practical and experiential teaching activities. Among them, a popular model worldwide that fits the objectives of the 2018 General Education Program is David Kolb's Experiential Learning theory. The theory has shown that the educational mindset has shifted from placing the teacher at the center to focusing on the learner as the central figure (Nguyen, 2017). Constructing teaching activities according to the experiential learning theory process aligns with current innovations, allowing students to develop comprehensively and meet the required standards (Nguyen & Bui, 2017). This study uses David Kolb's definition of experiential learning to construct teaching scenarios.

Experiential learning theory views learning as "the process through which knowledge is created through the transformation of experience. Knowledge is the synthesis of grasping and transforming experience" (Kolb, 1984, p. 40). Learning is seen as a process, not just an outcome, marking a significant shift in experiential learning compared to traditional learning methods. Initially, "competency" is a commonly used term with many different understandings. However, when discussing competency in humans and a specific field, we refer to mathematical competency, where an individual may achieve higher or lower levels depending on the objective. A suitable definition for "competency" and "mathematical competency" is: "Competence is someone's insightful readiness to act appropriately in response to the challenges of given situations" (Niss & Højgaard, 2019, p.12) and "A mathematical competency is someone's insightful readiness to act appropriately in response to a specific sort of mathematical challenge in given situations" (Niss & Højgaard, 2019, p.12).

Thus, from the above definition, mathematical competency is linked with "activity" and "mathematical challenge." Practical and experiential activities can meet the requirements for developing learners' competencies. During experiential activities, students are encouraged to be autonomous, self-experimenting, interactive, and exploratory (Nguyen & Bui, 2020). This creates opportunities to help students develop core competencies (Dang, 2018). Many studies have shown that experiential learning enhances students' mathematical competencies, motivating them to learn. Students actively participate in group work, honing their ability to delegate tasks and discuss group activities (Duong et al., 2021; Chesimet, 2016).

Research has shown the benefits of experiential learning in teaching spatial geometry. However, we have observed that student activities typically involve small objects (such as prisms and pyramids) and applications in modeling geometric problems. In reality, the direct experience of spatial geometry to enhance mathematical competencies has yet to be addressed explicitly. Recognizing this, we raise the question: "How can practical and experiential activities enhance mathematical competence in learning spatial geometry?"

2. Method

2.1 Research Design

The study is an exploratory case study. First, we designed a teaching scenario in order to develop mathematical competence under the 2018 General Education Program in Mathematics. This scenario was then implemented in a classroom setting. We observed students' actions and products to describe the manifestations of their mathematical competence.

2.2. Participants

The teaching scenario was experimentally conducted with 34 twelfth-grade students and 34 eleventh-grade students in Tay Ninh Province, Vietnam. The students worked in groups (10 groups), each consisting of 5 to 7 students. The experiments occurred during the twelfth graders' first semester and the eleventh graders' second semester.

2.3. Problem

This study focuses on the concepts of perpendicular and parallel relationships in space within the Grade 11 mathematics curriculum. We developed an experiential learning scenario of "Determine the center of the classroom with the tools available in the room". This activity enables students to apply their knowledge of spatial geometry to solve real-world problems. Indeed, by relying on perpendicular and parallel relationships, students must give arguments to ensure that the determined position satisfies the definition agreed upon by the class.

2.4. Learning activities

The scenario was conducted in three phases in Table 1.

Table 1. Activity phases

	Form	Activities
Phase 1 (90 mins): Definition of students' "classroom center."	Group	Students worked in groups to solve the problem of "Defining the center of the classroom."This is the foundation for "Determining the center of the classroom". During this process, students demonstrated the existence and uniqueness of the classroom center.

		At the end of Phase 1, the teacher summarized the problem and asked the class to vote by raising their hands to select one definition of "classroom center" to use as the basis for the next phase. Additionally, the teacher assigned each group the task of "determining the classroom center using tools available in the class." Subsequently, each group presented their results on a Roki paper.
Phase 2 (conducted outside the schedule): Problem solving.	Group	The students carried out the assigned task in groups during the afternoon after school hours. After determining the center of the classroom, each group completed a report that included diagrams, tools used, and the steps they followed.
Phase 3 (45 mins): Groups present problem-solving approaches on the flip chart paper - analyze among groups about their methods.	Whole class	Group representatives presented the steps taken and the tools their group used to determine the center of the classroom. Other groups analyzed and posed questions to the presenting group. The students provided feedback based on their understanding of perpendicular relationships in space.

2.5. Data Collection and Analysis Method

This study examines the feasibility of developing students' mathematical problem-solving and communication competencies. We analyze their manifestations in the scenario by using some information in Table 2.

Table 2. Definition and expression of mathematical competencies.

Competencies	Defined according to Niss & Højgaard, 2019	Expression under the 2018 General Education Program in Mathematics
Mathematical problem handling competency-posing and solving mathematical problems	"This competency involves being able to pose (i.e., identify, delineate, specify, and formulate) and to solve different kinds of mathematical problems within and across a variety of mathematical domains, as well as being able to critically analyse and evaluate one's own and others' attempted problem solutions. A key aspect of this competency is the ability to devise and implement strategies to solve mathematical problems." (p. 15)	- Identify and detect mathematical problems that need to be solved. - Select and propose methods and solutions for problem-solving. - Utilize compatible mathematical knowledge and skills (including tools and algorithms) to solve the posed problems. - Evaluate the proposed solution and generalize it for similar problems.
Mathematical communication competency-communicating in, with, and about mathematics	"An individual's ability to engage in written, oral, visual or gestural mathematical communication, in different genres, styles, and registers, and at different levels of conceptual, theoretical and technical precision, either as an interpreter of others' communication or as an active, constructive communicator, constitutes the core of this competency." (p. 17)	- Understand, read, and take notes on necessary mathematical information presented in mathematical text or spoken or written by others. - Present and express (either orally or in writing) mathematical content, ideas, and solutions in interaction with others (with appropriate requirements for completeness and accuracy). - Effectively use mathematical language (numbers, letters, symbols, diagrams, graphs, logical connections, etc.) combined with ordinary language or body movements when presenting, explaining, and evaluating mathematical ideas in interaction (discussion, debate) with others. - Demonstrate confidence when presenting, expressing, asking questions, discussing, and debating mathematical content and ideas.

Students' behaviors will be observed through various data sources (Table 3), including students' productions on Roki papers, audio recordings of student interactions during group work, and visual documentation of student behavior during presentations via photos and videos. Student activities are observed and analyzed through the following data: roki paper, photos, audio recording, video recording of discussion, and students' presentation.

Table 3. Expression of observed competencies

	Analysis		Data
	Competencies	Expression	
Phase 1	Mathematical communication competency - communicating in, with, and about mathematics.	Comprehending the problem statement by listening and reading.	Audio recording
	Mathematical communication competency - communicating in, with, and about mathematics.	Rational explanation of presenting, expressing, discussing, and debating mathematical content, ideas, and solutions in interaction with others.	Video recording of student's discussion
	Mathematical communication competency - communicating in, with, and about mathematics.	Reasonable use of mathematical language in conjunction with everyday language to prove the existence and uniqueness of a room's center.	Video recording of student's discussion
Phase 2	Mathematical problem handling competency - posing and solving mathematical problems	Identifying problematic situations; collecting, organizing, explaining, and assessing the reliability of information. I am choosing and establishing problem-solving methods and procedures.	Video recording of student's discussion
	Mathematical problem handling competency - posing and solving mathematical problems	Executing and presenting problem-solving solutions.	Roki paper
Phase 3	Mathematical problem handling competency - posing and solving mathematical problems	Evaluating implemented solutions and reflecting on their value.	Presentation

3. Findings

3.1. Phase 1

All ten groups presented definitions of classroom center. Students were able to listen and read the topic when the teacher asked them to present the definition of the center of the room. When asked by the teacher to present a definition for "the center of the room," students questioned, "What kind of point is the center?" They proposed definitions for "the center of the room." In class 12L, students found ten definitions; in class 11H, they found 4. Then, the whole class raised their hands to vote to choose a definition as the basis for Phase 2. The chosen definition was "The center of the room is the point equidistant from the 8 vertices of the room." However, in the solution implementation phase, this definition poses a challenge for students that they failed to connect two vertices located on the diagonal. In response, the definition was "the center of the classroom is at half the height of the classroom from the center of the floor." Students found it feasible and unanimously chose it as the foundation for Phase 2.

In Phase 1, students were tasked with proving the existence and uniqueness of the room's center, discussing, "In what sense does it exist? Mathematically or physically?" This demonstrates the students' analytical approach to understanding the problem- They reasoned, "considering the ideal case of walls, without considering protruding parts (like lectern)", "if there were such lecterns, drawing it out would be unbalanced", "if there are more items inside, the center of the room changes." We realize that the student's idea is to consider the classroom to be a rectangular, without objects inside.

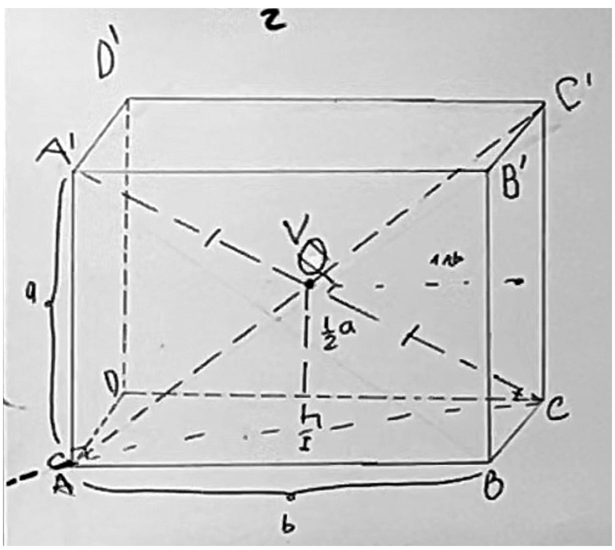

Figure 1: Student's drawing on Roki paper

The student presented: "This point is the only point because through the line AC'. I can only draw a perpendicular line and cut this line in two at this point V. So there never exists a second point V that satisfies those properties." However, the requirement to "prove existence" has not been explained explicitly by students. Students can only reason that because the room under consideration is rectangular, the length, width, and height have been measured, so there must be a point equidistant from the vertices as the center. Almost all groups have difficulty in the "proving existence and uniqueness" part, because this is a reasonably new requirement they have never encountered previously.

The activities focused on mathematical communication competency, facilitating discussions during group work, and group debates during presentations. Students proposed definitions based on their understanding of the problem statement. Students presented and debated with their classmates to prove the existence and uniqueness of the room's center.

3.2. Phase 2

Students determine the center of the classroom with the items available in the classroom. The teacher suggests students for using an extra roll of thread or a laser pen to create favorable conditions. However, students are still encouraged to use available items in the classroom for better evaluation. Observing phase 2, we noticed that students used the rulers already in class and proceeded to the following three stages, respectively:

- Stage 1: Determine the "center" of the classroom floor.

- Stage 2: Take a perpendicular from the center of the floor and measure the height of the classroom.

- Stage 3: Measure half of the height of the classroom.

In stage 1, students go through 5 steps:

- Step 1: Determine the length of the room.

- Step 2: Determine the width of the room.

- Step 3: Take the midpoint of the room's width.

- Step 4: Take the midpoint of the length of the room.

- Step 5: Determine the intersection of the two-perpendicular bisector above is the center of the room's floor.

From here, students have chosen and established a problem-solving process.

In stage 2, using a 1m-long graduated ruler available in each classroom, students created a 1.5m-long ruler from the curtain rack in the classroom. Students placed the ruler close to the wall to ensure perpendicularity in the measurement. Because they cannot touch the ceiling, students use additional chairs. However, groups 3 and 4 use curtain brackets and do not place them in the corner of the wall, which does not ensure accuracy during the measurement process.

In stage 3, from the position of the center of the classroom floor and the measured height, groups take half the height and build from the center of the classroom floor to half that height.

We found that students implemented and presented solutions to solve problems. However, students ignore perpendicular elements. Placing tools such as rulers and curtain racks does not ensure a perpendicular relationship between straight lines and planes.

Finally, in Phase 2, the students demonstrated their mathematical problem-solving competencies as they presented solutions to the problem. After measuring in the classroom to determine the center's location, the students documented their solutions on Roki paper. From this process, we observed that the problem-solving approaches of all groups followed a relatively similar procedure. The students only used different tools at specific measurement steps. From this data, we can summarize the steps performed and the tools that the groups chose to use.

3.3. Phase 3

The students evaluated that the implemented solution did not ensure perpendicularity when groups presented from the base center upwards with a perpendicular segment to indicate the center of the room. At that point, the teacher asked: "How could you ensure that your segment is perpendicular to the room's floor?" The group of student used a table to ensure parallelism from the tiled line to the table's edge. Other students began asking questions about using the group's table to evaluate the group's problem-solving solution. From there, the students constructed a segment from the center of the classroom floor to the edge of the table and continued upwards to reach the center of the classroom.

Student 1: “The group tells me and the class how you use the table. If you push the table here, then pull it up to pass. The problem is that there is still a mistake, maybe your point on the room's floor is not the correct position of the center of the room's floor.”

Student 2: “Place perpendicularly. Measure and determine where its center is, then measure it again above.”

Student 1: “When you put the table in what position?”

Student 2: “Place the table's edge in the position of the tile border. Put the long ruler and eke ruler back to measure.”

Student 1: “How will you measure next?”.

Student 2: “The measurement on the brick, how many centimeters I should go over, and how many centimeters I should go up, will be taken so that it lies right at the marked ground position. Then, from the table, retake the same thing.”

Initially, the students focused on finding solutions to the problem by measuring the room's height and overlooked ensuring perpendicularity and parallelism in space. During this phase, questions from both the teacher and the students aimed to help students reconsider their solutions and present arguments to prove perpendicularity and parallelism in space. The students could reasonably explain and debate mathematical content and solutions through interactions with class members.

4. Discussion and Conclusion

Based on David Kolb's definition of experiential learning, this study provides a spatial geometry teaching scenario through practical and experiential activities, and meets the requirements of the 2018 General Education Program in Mathematics. The research aims to develop mathematical competencies in high school students. Students are trained in mathematical communication and problem-solving competencies by determining the center of a room, which is associated with knowledge about perpendicular and parallel relationships in space.

The findings demonstrate that the teaching scenario can develop specific mathematical competencies in students, affirming the effectiveness of experiential learning in mastering and applying spatial geometry concepts practically (Jablonski & Bakos, 2022). This approach also improves students' mathematical competencies, particularly in spatial geometry, thereby supporting the comprehensive development of students' competencies and qualities under the new goals of Vietnam's general education. Regarding skills, it can be observed that students have made progress in analyzing real-life problems and applying their learned knowledge to solve these problems in practice (Davidovitch et al., 2014).

We have observed similarities between this study and others applying David Kolb's experiential learning theory in developing practical and experiential activities. Many studies on mathematics education have applied this method and recognized its effectiveness in enhancing student participation and understanding. This research aligns with the broader objective of bridging the gap between theoretical content and practical activities. It is a prevalent theme in contemporary educational research. The study emphasizes physical interaction with spatial objects. This practical approach is designed to deepen understanding by directly engaging students with the physical properties of geometric concepts. This study particularly relates to the Vietnamese context, and aligns with the goals of the 2018 General Education Program in Mathematics.

This study can be easily implemented in high schools. The only infrastructure needed to conduct it is a classroom, and the cost of teaching is also very low. The study highlights the benefits of applying mathematical concepts to real-life situations, enhancing understanding, and fostering deeper connections among students. Additionally, with students working in groups, presenting reports, and discussing, they assess the knowledge integrated into the scenarios, demonstrating a "student-centered" approach and allowing the class to operate autonomously.

The study's strengths include a clearly defined experimental framework and the construction of practical and experiential activities that enhance students' understanding and application of spatial geometry concepts. However, this research may encounter typical limitations associated with practical and experiential studies, such as potential challenges in generalizing findings due to the study's specific context or reliance on physical interaction, which may only be feasible in specific learning environments. Additionally, the time required to conduct the teaching might be relatively significant. Moreover, we have only been able to implement teaching in two classrooms.

Overall, the study has achieved its objective by demonstrating that practical and experiential activities in teaching spatial geometry for Grade 11 can significantly cultivate their mathematical competencies, mathematical communication skills, and problem-solving abilities. The research has added realistic teaching scenarios where students work in an expanded space to apply the specific knowledge about perpendicular and parallel relationships in space, meeting the requirements of the 2018 General Education Program in Mathematics. It has significantly contributed to mathematics education and provided a practical framework that can be easily implemented in educational environments.

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