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| RESEARCH ARTICLE

Investigating the Role of Graphic Geometry in Enhancing the Spatial Ability of Engineering Students

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| ABSTRACT
Graphical geometry is known as one of the basic subjects for improving spatial abilities of students at Kabul Polytechnic University and other engineering faculties. The main question is whether the methods of teaching graphic geometry with common methods at Kabul Polytechnic University meet all the demands that are included in the curriculum of various departments of this university? To answer this question, it is necessary to review and study basic studies on the factors of acquiring spatial abilities and the role of teaching the subject of graphic geometry as a main factor for learning and other inhibiting methods for increasing the spatial ability component. To verify the results of the research, two spatial ability tests were selected and, in these tests, pre-test and post-test were conducted using a quasi-experimental method with a control group in two disciplines with two different educational programs and the results of the tests were analysed. The results obtained from the tests on increasing spatial abilities show that the methods of teaching applied geometry have not significantly increased the spatial ability of students. In some cases, it has been tested with a significant reduction in both groups. One possible reason for these results can be attributed to the teaching of the subject of graphical geometry using conventional and classical methods at this university.

| KEYWORDS:

Spatial ability, conventional methods, applied geometry, spatial orientation.

| ARTICLE INFORMATION

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1. Introduction

Exercise and space are one of the most important abilities for engineering students that have been tried to be developed in the teaching of spatial volumes. In the last few decades, numerous studies have been conducted on various aspects of space and its development in the research field. Although the center of these studies, the perspective of the method and the development of findings about the nature of spatial space have not been formed, there is a consensus on increasing this skill in understanding volumes and spaces. Among the studies and categories mentioned for space, we can mention the studies of Mayer (1994), Tartre (1990), Luman (1988) and Carroll (1993).

Despite this perspective, many methods and approaches have been developed to strengthen this skill and address the shortcomings of students, whether in the field of construction or in other fields that require a comprehensive understanding of volume or space. However, it seems that in Afghanistan, generally relying solely on old drawing methods to increase this important skill has created an obstacle to its significant improvement. Teachers and professors of drawing geometry - as a subject that is entirely in the service of increasing this skill - refer to the syllabus and objectives set for this subject to justify their educational approaches and methods.

Although some professors have recently made innovations to increase students' understanding of two-dimensional and three-dimensional space, in general, in Afghanistan, comprehensive and developed theories about the development of spatial ability in the form of "drawing geometry" in the applied geometry course have not been developed. In order to develop studies in the

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field of spatial ability in architecture, the present study, using spatial ability assessment tests, sought to provide a better understanding of the effectiveness of the applied geometry course on the spatial ability of architecture students.

2. Literature Review

Despite the conclusive proof of the direct effect of teaching graphic geometry on increasing spatial ability (Kospentaris, Gittler & Gluck, 1998; Spyrou, 2010; Leopold, 2005), in recent years, it has been observed that one of the concerns of researchers in this field is the lack of effect of some geometry teaching methods on increasing this skill. Some have attributed this inefficiency to the presence of complex two-dimensional images. which does not provide students with the possibility of understanding through analysis (Martin-Gutierrez et al., 2010) and some others have considered the replacement of manual drawing methods and making 3D models in basic education with computer-aided drawing software (CAD-system) as a cause of reducing spatial ability in some institutions (Leopold, 2005). Testing various methods of teaching drawing geometry, such as teaching through AutoCAD software and holding workshops with making tangible volumes (Takeuama, Maeguhi, Chibana & Yoshida, 1999), is a way to find more suitable methods that has received much attention. The impact of origami education on the geometry teaching process (Boakes & Pomona, 2009) The creation of applications that allow students to freely change the viewing angle and give students greater freedom of action, such as the DIEDRO-3D software (Martin-Gutierrez et al. 2010) and the Dynamic Geometry Instructional System (Nagy-Kondor, 2010), which increase students' connection with graphic geometry problems and of course improve students' spatial ability and provide enjoyable lessons. In addition to various programs, new computer tools for understanding three-dimensional geometry stimuli (called virtual reality or VR) have even made it possible to compensate for students' shortcomings and equalize the level of spatial ability in a class (Kaufmann, Steinbugl & Gluck, 2005).

After years of successful graphic geometry classes at MTU University in America, Sorby outlines the methods used in this course to enhance spatial visualizations, hand-drawing (sketching) and creating three-dimensional models, and identifying weak students and providing them with extracurricular classes (Sorby, 1999).

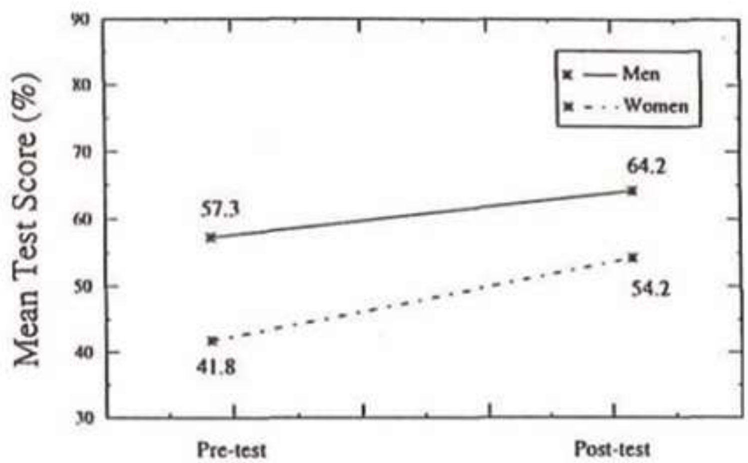

Figure 1. Results of scores obtained in the pre-test and post-test in 2 tests MCT, MRT and PSVT at University of MTU with Source Sorby, 199

At the University of Granada in Spain, they first examined the impact of traditional architectural education methods on spatial ability and then presented methods for influencing it. The results were as follows: “Sequential curricula, especially those taken from the European higher education system, have significantly reduced the spatial abilities of students pursuing technical degrees” (Sanjuan, Robles & Montes Tubio, 2014). In Afghanistan, to the date of this research, no quantitative or qualitative study has been conducted on the relationship between the role of descriptive geometry and the development of spatial ability for students of engineering faculties and other disciplines that require this skill.

3. Methodology

This study used a quasi-experimental design with a control group. A type of design in which the selection and assignment of subjects is done randomly for any reason is called a ”two-group, non-identical design with pre-test and post-test” (Sarmad et al., 2016). In this method, the dependent variable is measured once before the manipulation and the independent variable and again after the experiment and manipulation of the experimental variable. Table 1 shows the quasi-experimental design used in the study.

3.1 The theoretical role of spatial ability

Spatial abilities have occupied a large part of the research in the field of educational psychology, but since the 1920s or 1930s, when specialized studies on this topic began, unlike other types of skills, there is no general consensus on the true meaning of the term "spatial abilities". For example, some believe that "spatial abilities are the ability to manipulate objects or designs in the mind" (Kahle, 1983) and some believe that "spatial ability includes the complex and multiple manipulation of spatial information presented" (Linn & Petersen. 1985). Meanwhile, others believe that "spatial ability is the mental manipulation of spatial information that a person performs, in the form of a given spatial shape by consciously manipulating it by changing it, such as rotating, tilting, changing position, or other changes" (Salthouse, 1990).

Guilford and Lucy (1956) defined two principal factors, spatial rotation and spatial orientation, which had previously been defined as "the rotation of objects embodied in the mind." Terson (1950) interpreted the S_1 factor as the effect of rotations on the ability to recognize a shape (as seen from different angles, e.g., from the front, above, and around).

The creation of several articles on the subject of classifying spatial skills is evidence that there is no single and universal definition of spatial ability. Mayer (1994) considers spatial ability to consist of five elements. These five elements are as follows: spatial perception, spatial rotation, spatial communication and spatial orientation.

A problem that this classification will face is the overlap of categories on the same activity. For example, there are several activities that can be included in both spatial communication and orientation. Tartre (1990) proposed a new classification scheme based on the mental processes used to perform a given action, following the previous research of McGee (1979). He believes that two distinct factors can be considered for classifying spatial ability: "spatial visualization" and "spatial orientation".

Spatial visualization has the properties that involve mental movements of an object, and spatial orientation is the ability of the mind to change the point of view, while the object is fixed in space. Spatial relations are themselves expanded into two subsets: mental rotation and mental deformation. The important difference between these two subsets is that with "mental rotation" the entire object is moved, while with "mental deformation" only a part of the object is moved to one side. This classification scheme is shown in Figure 2.

Research into spatial visualization abilities continues to explore new factors and develop new tests for these factors. One such ability is dynamic spatial ability, first identified by Pagrino (1991) and commonly used in computerized and verbal tests, such as detecting a volume approaching a target, or detecting the location of the intersection of two objects moving simultaneously.

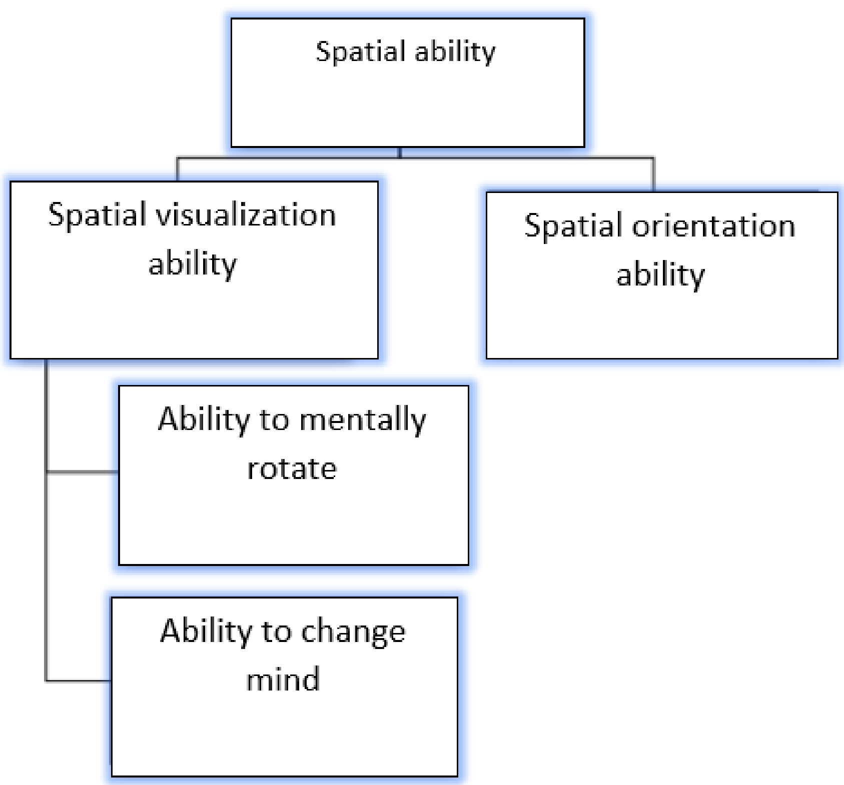

Figure 2. Tartre's classification of spatial visualization abilities

Source: Tartre, 1990

3.2 The importance of spatial ability

In recent years, several educational articles have been presented on the importance of spatial ability. Among them, we can mention the article by Smith (1964). He concluded that there are 84 jobs in which spatial ability plays a significant role. The result of the research of Mayer (1994) showed that for technical professions such as engineering, spatial ability, especially the ability to "mental rotation", is of particular importance. In the research conducted by Norman (1994), the result was that the level of spatial ability of an individual is the best estimator of the position of individuals in the ability to interact and use computers.

Brick (1993) also says that strong spatial abilities are necessary and essential for understanding structural chemistry and basic chemistry. McKim (1980) points out that visual ability is necessary not only for artists but also for those who serve in scientific and technical jobs. He gives several examples of discoveries or advancements in technological advancements throughout history that were made through vision and visualization and had a long-lasting impact on society, such as Watson's discovery of the helical structure of DNA, and inventions such as the fluorescent lamp and Tesla's A-C generator. He also points to Einstein's continued use of his thinking through visual thinking and images, saying that it was difficult for Einstein to incorporate his thoughts into words as a secondary structure.

The main axes of prerequisite courses to strengthen the basic skills of architecture students in the national curriculum are imagination, spatial visualization and expressive skills and strengthening creativity.

In 2010, Ms. Jagmor Klimki from Georgia Tech University expressed the importance of 3D spatial visualization in architecture as follows: "Many architects talk about the different dimensions of 3D mental visualization affecting their design process, especially when working with 2D drawings and images. In general, it indicates that every architect should visualize the 3D building in his mind by looking at 2D drawings and in this way, i.e., visualize the 3D building, easily understand the different dimensions of that building. This research in the field of architectural education has shown that "spatial visualization ability" plays an important role in carrying out architectural design. As "spatial ability" is known as an essential skill for architects in 3D mental visualization. In this field, research has been conducted that confirms the direct relationship between 3D visualization and spatial ability using various tests (Yukhina; 2007, Ho.2006). In an article titled “Architects See Buildings from the Users’ Perspective” in 2007, Martin Brussam and Christoph Holscher introduced the term “navigation” in an article about the abilities of architects in design. In their definition of this term, they claim that “navigation” is used in the field of architectural design and refers to the ability of an individual to “spatial orientation” which leads to the correct design of access routes in a building. With the help of the correct design of access routes, we will be able to easily reach the desired location in the place we are in.

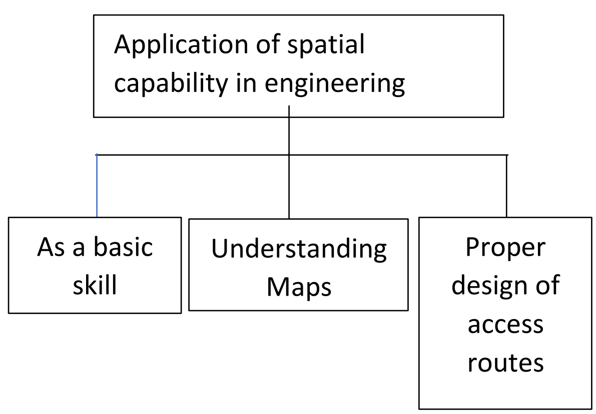

Figure 3. Diagram of the importance of spatial ability in engineering

3.3 Increasing spatial capabilities in engineering faculties

Little, Trleki, and Newcomb (2008) demonstrated that improvements in spatial ability achieved through training are durable and long-lasting, and that continuous training in rotational exercises is more important for women. These statements are essential and crucial for the idea that all individuals can potentially improve their spatial skills with appropriate training and education, and that having superior innate ability is not necessarily a prerequisite for success. The findings also emphasized the importance of training consistency and appropriate distribution of training time for spatial skills. Thus, research has shown that spatial abilities are not fixed and can be improved.

In engineering sciences, Surbai's (2009) interpretive studies have shown that three-dimensional skills develop, especially for women. Michigan Technological University held a conference and workshop to increase students' spatial abilities one semester and also organized a course for students who scored less than 60% on the Purdue Spatial Rotation Test (PSVT:R). Women who took this course scored higher than other women. Therefore, it seemed that the positive effect on their spatial abilities was sustainable.

In engineering schools and institutes, they often teach and draw and design buildings with the help of two-dimensional and three-dimensional drawings from the very first year of education, usually through the provision of specialized units or workshop units. During this training, the goal of the institutions and faculties and their expectations from students is to develop their ability to visualize space and three-dimensional shapes (Yagmur.2010). In the general specifications, program and syllabus of the national curriculum for 1400, the objectives and types of exercises and presentation of the courses are mentioned in detail. Basic courses are intended to strengthen the basic and essential abilities for the field of architecture. In order to increase "spatial ability" as a fundamental skill in architecture, courses must have a direct effect and courses must have potential effects. "Applied geometry" is the first course that has set its main goal as "increasing the ability to understand space and volumes" and is a course during the architecture course in which most of the objectives mentioned in it serve the views and benefits, and due to its three-dimensional drawing content, it can be an effective course in this field. Other basic courses, such as the introduction to design and architectural expression, can only be considered to have effects on this ability due to its drawing.

3.4 Subjects

Bachelor of Architecture Engineering students of Kabul Polytechnic University at the beginning of their basic education form the statistical population of this study. For this reason, in order to eliminate the effect of the instructor and the effect of other courses, the students in the experimental group were selected from the first semester students of the Bachelor of Architecture Engineering of the University of Civil Engineering and the University of Chemical Engineering of the Polytechnic University (the instructors and other courses offered in the first semester of the academic year are different in the two universities). The tests were conducted in the first semester of the academic year 1402 and 1403. The selection and assignment of the subjects to the experimental groups was done by convenient sampling. 24 students from the Architectural Engineering Department of the Faculty of Civil Engineering and 50 students from the Chemical Engineering Department of the Kabul Polytechnic University were considered as the experimental group. The control group students, due to the elimination of the factor of academic aptitude and the effective effect on spatial ability, were selected from the Computer Engineering Department of the Polytechnic University.

Table 1. Pretest and posttest design with control group for future research

Group	Pres -Test	Independent variable	Post – Test
Test Group	Subjects' performance on specific tests	Training method	Subjects' performance on specific tests
Control Group	Subjects' performance on specific tests	_____	Subjects' performance on specific tests

3.4 Tests

3.4.1 MRT Test

As explained in the "Classification of Spatial Ability Factors" section, "spatial visualization" and "spatial orientation" are two dimensions of spatial ability. Spatial visualization has components that involve mental movements of an object, and the most valid test available in this regard is the Vandenberg and Cure Mental Rotation Test (MRT). This test involves items in which a block shape is shown, then rotated about one or two axes. Two of the four given answers must then be selected that are identical to the given block arrangement. The two items shown in Figure 2 are sample questions from the MRT test. This test is also available in an open-ended format (Mohler, 2006).

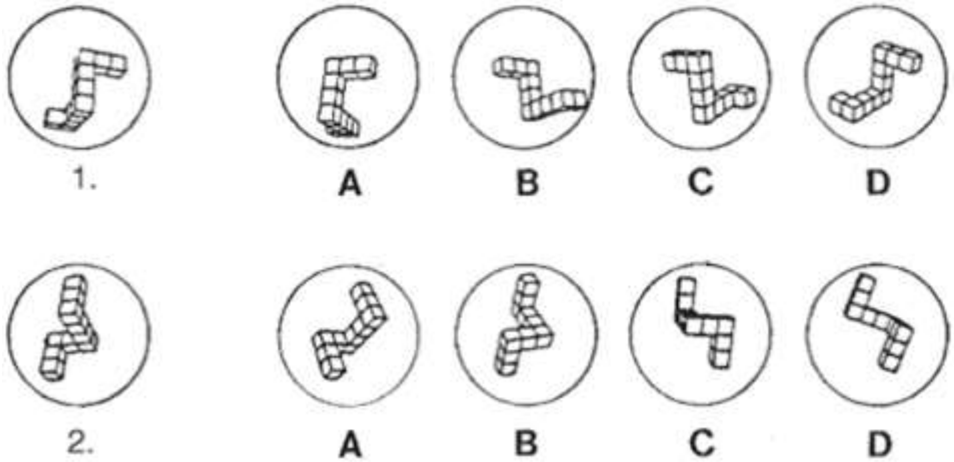

Figure 5. Items 1 and 2 of the Mental Rotation and Nedenberg and Geise Test Source: Mohler, 2006

3.4.2 PSVT Test

"Spatial Orientation" involves the ability of the mind to change the point of view. While the object is considered fixed in space. The test selected in this section is the PSVT (1976). Spatial tests have been generally criticized because of the ease with which subjects rotate the object. Guay tried to address this problem in 1976 by designing a valid test called the Purdue Spatial Rotation Test (PSVT) which included visualization, rotation and presentation (orientation). The viewing angle (orientation) section required the visualization of an object from different angles. The viewing angles from different corners of a cube are shown in Figure 6 (Guay, 1977).

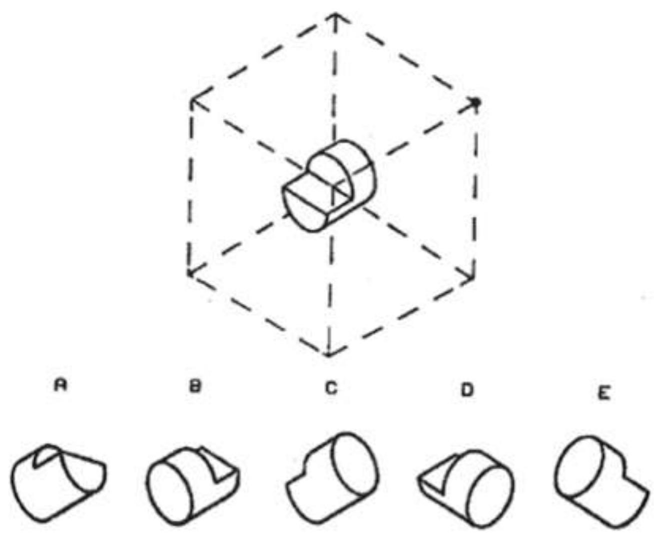

Figure 6. PSVT test. Visual angle section
Source: Guay,1977

3.5 Experimental Procedure

The experimental procedure included a researcher-made questionnaire to obtain information about gender, grade, background, educational background, level of mastery and familiarity with 3D software, hand-drawing techniques (sketch and doodle), and the amount of use of games and applications and the type of their environment, and the implementation of similar tests to measure spatial ability according to the experimental design in two stages of pre-test and post-test.

3.6 Pre-test

The pre-test was conducted by administering the two aforementioned tests before the applied geometry lesson sessions for the experimental groups, and for the control groups in the first week of the beginning of the academic year.

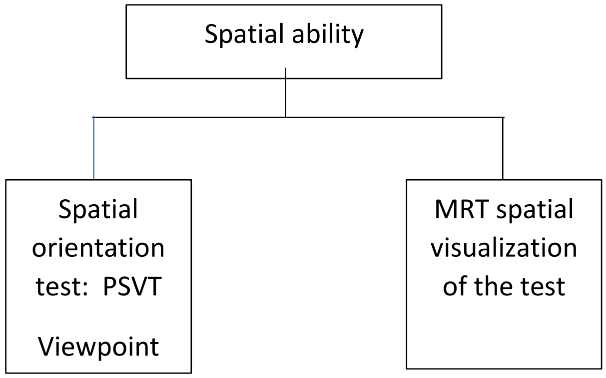

Figure 7. Tests by Tartre category

3.7 Post-test

The post-test was conducted using spatial ability tests. Many explanations were given with examples to ensure that the students understood the test process properly before the test.

4 Research findings

Table 2. Performance results of students in the Faculty of Civil Engineering

Descriptive statistics of test results of MRT and PSTV			
Numbers	Average	Faculty of Civil Engineering Exam Group	
50	6/0600	Per – Test MRT	First test
50	5/2200	Post-Test MRT	
50	9/8200	Per-Test MRT	Second Test
50	9/2800	Post- Test MRT	

Table 3. Performance results of students in the Faculty of Chemical Engineering

Descriptive statistics of test results of MRT and PSTV			
Numbers	Average	Faculty of Chemical Engineering	
22	11/1818	Per – Test MRT	First test
22	9/3727	Post-Test MRT	
22	11/500	Per-Test MRT	Second Test
22	10/9318	Post- Test MRT	

Table 4. Performance results of Computer Science Faculty students in exams

Descriptive statistics of test results of MRT and PSTV			
Numbers	Average	Control Group	
32	5/8438	Per – Test MRT	First test
32	6/4063	Post-Test MRT	
32	9/1250	Per-Test MRT	Second Test
32	9/9688	Post- Test MRT	

5. Conclusion

The research findings show that conventional methods of teaching drawing geometry not only do not increase students' spatial abilities (which is clearly mentioned in the title and objectives); but also that students' performance in both faculties showed a non-significant increase due to test repetition. The study of the success of drawing geometry teaching in achieving the goals of the national curriculum, which was conducted in two faculties with two different educational programs and two different instructors, and using international standard tests for measuring spatial ability, MRT and PSVT (which test all dimensions of spatial ability), indicates a worrying disruption in students' abilities to solve spatial problems and understand space.

The above result, in turn, is a declaration to begin a review of contemporary traditions of engineering education. The experiences of many experienced professors in Afghanistan indicate the need for students to get architectural concepts off the paper and touch space, but the gap in scientific review and criticism using international methods must also be filled by researchers.

The correspondence of the key words in the curriculum council's booklet with what is in the field of spatial ability research raises the question of whether what is mentioned in this curriculum is just a rewriting and translation of widely used and heavy vocabulary, without paying attention to the application of its meanings?

This research was conducted quantitatively. There has been a significant increase in unanswered questions in spatial tests. Speculations to find the qualitative causes of this significant decrease in performance in spatial tests have been linked to changes in students' thinking patterns and strategies in solving spatial problems. Therefore, those interested in research in this field are advised to study students' problem-solving methods qualitatively in addition to quantitatively examining students' performance.

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