The effect of architectural education on spatial abilities

El efecto de la educación arquitectónica en las habilidades espaciales

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Abstract

This study aims to investigate how architectural education influences the development of spatial abilities. It specifically examines whether architectural education enhances spatial abilities and how performance differences between high-achieving and low-achieving students evolve when exposed to the same training. A correlational method with a single-group, pre-test-post-test design was used. This approach measured the spatial ability development of the same sample group (n=264) over a training period. Participants, selected through convenience sampling and quota sampling methods, were administered a spatial ability test at the beginning of their architectural education and again at the end of the first semester to evaluate the educational impact on spatial abilities. Comparing the initial and final tests revealed a statistically significant improvement in spatial ability (µPre-test=18.83, µPost-test=22.56, p<.001). Students with lower pre-test scores exhibited greater improvements than those with higher initial scores. Correlation analysis between pre-test scores and score increases revealed a strong, inverse relationship (r=-0.523, p<.001). A visual graph categorizing students into five groups based on pre-test success demonstrated the same trend. This study provides novel insights into how architectural education enhances spatial abilities, specifically focusing on the contribution to the development of the mental rotation component, which has not been addressed in previous studies.

Resumen

Este estudio tiene como objetivo investigar cómo la educación arquitectónica influye en el desarrollo de las habilidades espaciales. Examina específicamente si la educación en arquitectura mejora dichas habilidades y cómo evolucionan las diferencias de rendimiento entre estudiantes de alto y bajo logro cuando reciben la misma formación. Se utilizó un método correlacional con un diseño de grupo único, pretest–postest. Este enfoque midió el desarrollo de la habilidad espacial en el mismo grupo de muestra (n=264) a lo largo de un periodo de formación. Los participantes, seleccionados mediante muestreo por conveniencia y muestreo por cuotas, realizaron una prueba de habilidad espacial al inicio de su formación en arquitectura y nuevamente al finalizar el primer semestre, con el fin de evaluar el impacto educativo en dichas habilidades. La comparación entre las pruebas inicial y final reveló una mejora estadísticamente significativa en la habilidad espacial (µPre-test=18.83, µPost-test=22.56, p<.001). Los estudiantes con puntajes más bajos en el pretest mostraron mayores mejoras que aquellos con puntajes iniciales más altos. El análisis de correlación entre los puntajes del pretest y el incremento de puntajes reveló una relación fuerte e inversa (r=-0.523, p<.001). Un gráfico visual que categorizó a los estudiantes en cinco grupos según su éxito en el pretest mostró la misma tendencia. Este estudio aporta nuevas perspectivas sobre cómo la educación

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arquitectónica mejora las habilidades espaciales, centrándose específicamente en la contribución al desarrollo del componente de rotación mental, que no ha sido abordado en estudios previos.

Keywords:
architectural education; spatial ability; mental rotation; cognitive development

Palabras Clave:
educación arquitectónica; habilidad espacial; rotación mental; desarrollo cognitivo

Introduction

Architectural education and the use and development of 3D spatial abilities are closely intertwined cognitive phenomena. In the literature, the concept referred to as 'spatial ability,' 'spatial intelligence,' or 'spatial skills' carries similar meanings and essentially denotes the capacity to create, preserve, and manipulate two-dimensional and three-dimensional images in the mind (Lohman, 1979), as well as to envision new configurations of objects resulting from such manipulations (Mayer & Sims, 1994). Since architecture as a discipline is fundamentally concerned with the three-dimensional perception, arrangement, and organization of the physical environment within human living spaces, spatial abilities play a critical role at nearly every stage of the architectural design process. Consequently, fostering spatial abilities is one of the primary objectives of architectural education.

Despite the importance of spatial abilities in architecture, architectural research on this topic remains limited compared to fields such as mathematics, geometry, and educational sciences. Beyond a few notable contributions (Berkowitz et al., 2021; Türkmenoğlu Berkan et al., 2020; Berkowitz et al., 2018; Sağıroğlu, 2017; Yağmur Kilimci, 2010; Nassar et al., 2010), there appears to be insufficient scientific research investigating this issue at the intersection of architecture and cognition.

Research problem

The central question of this study is how architectural education contributes to the development of spatial abilities. The ability to visualize, transform, and manipulate spatial phenomena is influenced by both hereditary factors and education, as well as cultural development (Sorby, 1999). Each student begins their education with a different level of spatial ability. Standard education systems typically provide equal information and techniques to all students, without accounting for individual differences. Given these differences, it is crucial to investigate whether architectural education plays a compensatory role in balancing spatial abilities among students. Understanding this process will provide insights into how structured learning environments influence cognitive development and whether they can effectively support students with varying initial ability levels. This study aims to fill this research gap by analyzing how spatial abilities evolve throughout architectural education and whether disparities among students diminish over time.

Significance of the study

Considering the content of pre-university education in Türkiye, it is evident that there are very few programs aimed at developing spatial abilities. In the Turkish national education system, spatial ability studies are limited to a few weeks of geometry classes in the natural science departments of high schools, where three-dimensional geometry topics are covered (MEB, 2020). The absence of activities designed to develop spatial abilities in pre-university education in Türkiye makes it particularly significant to conduct this study within the scope of Turkish universities.

At the time this study was conducted, a student entering architectural education in

Türkiye had not previously encountered a systematic education focused on developing spatial abilities. Aside from inherent factors, only the influence of their cultural environment, childhood games, or other personal experiences may have contributed to the differentiation in students' spatial abilities. Following this stage, students enter an educational model where spatial abilities are intensively utilized and developed. This dramatic shift in spatial ability development in Türkiye offers a unique opportunity to observe the impact of architectural education.

Aim of the research

This study aims to explore how architectural education contributes to the development of spatial abilities, focusing on the differences in spatial ability levels among students at the outset of their education and examining how these differences evolve through the educational process.

Research questions and hypothesis

The study is based on two hypotheses regarding the expected outcomes:

- Hypothesis 1: Architectural education will have a positive impact on the development of spatial abilities.
- Hypothesis 2: The spatial ability levels of students, who start the education at different levels, will converge by the end of one semester of education.

These hypotheses will be tested through a correlational research design, examining how spatial abilities evolve over time during architectural education.

Scope and limitations

This study specifically investigates the role of architectural education in spatial ability development within the context of Turkish universities. While the research provides empirical insights into this relationship, it does not account for personal experiences outside formal education, cultural influences, or pre-existing cognitive abilities that may affect spatial ability development. Additionally, the study is limited to first-year architecture students and does not examine long-term effects beyond the first semester.

The relationship between spatial ability and architectural education

Spatial ability enables the performance of mental operations, such as visualizing and manipulating three-dimensional objects, which are essential in many fields of engineering, art, and architecture (Lohman, 1979; Mayer & Sims, 1994). The ability to mentally visualize the three-dimensional view of a building from two-dimensional plan, section, and elevation drawings (Towle et al., 2005)—one of the most frequently used mental operations in architectural education and practice—is also closely related to spatial ability.

The first studies on spatial ability were conducted by Galton (2004) in 1883. Subsequently, researchers such as Thorndike (1921), Spearman (1927), and Thurston (1973) explored spatial ability using psychometric approaches. Later, McGee (1979), Maccoby and Jacklin (1974), Lohman (1979), Linn and Petersen (1985), and Maier (1996) focused on the components of spatial ability.

There is no consensus among researchers regarding the components of spatial ability. Although researchers have offered similar definitions on this subject, a conceptual confusion persists regarding the content of these definitions. For example, the ability to rotate objects in the mind has been discussed under various components: as 'spatial visualization' by McGee (1979), 'spatial relations' by Lohman (1979), 'non-analytical' by Maccoby and Jacklin (1974), and 'mental rotation' by Linn and Petersen (1985), Maier (1996), and Sezen Yüksel (2013). The component referred to as 'spatial visualization' has generally been used in studies to encompass a wide range of spatial activities, and in some cases, has even been used as a synonym for spatial ability. Kozhevnikov et al. (2005) made a distinction by dividing the visual cognitive style into two categories: object visualization and spatial visualization. The mental activities Kozhevnikov and colleagues (2005) described as spatial visualization are, in fact, expressions of spatial ability.

When considering the mental operations that require the use of spatial ability, four types of mental activities can be identified. In this study, the spatial ability components referred to as ‘mental rotation’, ‘establishing part-whole relationships', 'spatial orientation', and 'spatial visualization' are explained as follows:

- Mental rotation refers to the rotation of the whole or part of an object around a specific axis, or the rotation of the person's own position around the axis of the object.
- The component of establishing a part-whole relationship is two-fold. One aspect involves the ability to distinguish a particular shape from a complex pattern made up of multiple shapes. The other aspect involves the formation of a larger shape resulting from multiple shapes coming together in various configurations.
- The spatial orientation component refers to the ability to determine the position of other objects relative to the person's own line of sight or to the direction of another object.
- The spatial visualization component has been defined in various ways in the literature. In this study, spatial visualization is defined as the ability to mentally visualize manipulations such as adding or removing new elements, surfaces, or edges that are not present in the current state of the objects, or altering the dimensions/proportions of the objects.

The architectural design process is a challenging and highly complex process to conceptualize. The mental activities that occur during this process can take place in a diverse and interconnected manner. Alongside various mental skills such as 'linguistic intelligence', 'logical-mathematical intelligence', 'social intelligence', and even 'bodily-kinesthetic intelligence', as described by Gardner (2011) in his theory of multiple intelligences, 'spatial intelligence' also plays a crucial role in the architectural design process.

Almost every step of the mental performance involved in the architectural design process is connected to at least one of the spatial ability components mentioned above. For example, determining the orientations of the building to be designed within the current urban context is related to the 'spatial orientation' component; combining different parts of the building and visualizing the whole is related to the 'establishing part-whole relationships' component; mentally rotating the resulting composition and visualizing its views from various perspectives is related to the 'mental rotation' component; and manipulating features such as shape, size, and color of the design to achieve a different composition is related to the 'spatial visualization' component. Similarly, imagining the section of a three-dimensional structure or organizing and mentally combining two-dimensional plans, sections, and drawings to visualize its three-dimensional views are related to the 'spatial visualization' component. Such examples can be multiplied, as spatial abilities are continuously engaged in various stages of the architectural design process, from conceptualization to visualization and problem-solving.

Method

The study primarily investigates how architectural education influences the development of spatial abilities. In this context, two hypotheses were proposed. The first hypothesis posited that architectural education would enhance spatial abilities, and this hypothesis was tested. The second question was how the spatial abilities of students with varying levels at the beginning of their education would change as a result of the educational process. This hypothesis suggested that students with different levels of spatial abilities would converge towards similar levels through the contribution of education. To test the hypothesis, spatial ability tests were conducted with freshmen in the architecture departments of two universities in Türkiye.

The research model

In the study, quantitative research methods were employed to test the hypotheses. To investigate the development of spatial abilities from the beginning to the end of a semester of architectural education among the same students, the 'correlational method' (single group, pre-test-post-test design) was applied.

For the hypotheses of the study, the independent variable is 'architectural education', while the dependent variable is 'spatial abilities'. At this point, all other factors that could potentially act as confounding variables, such as students' personal experiences outside of architectural education, physical and psychological comfort, and other immeasurable factors, are considered limitations of the study.

For Hypothesis 1, which investigates the contribution of architectural education to the development of spatial abilities, a paired samples t-test was conducted. In Hypothesis 2, it is proposed that the difference between students with different levels of spatial abilities at the beginning of the education will decrease by the end of one semester. To test this, the differences between each student's pre-test and post-test scores were first calculated, aiming to quantify the spatial ability gained through education. Subsequently, correlation analysis was performed, considering both the pre-test scores and the difference between pre-test and post-test scores.

The methodological structure of the research is summarized in Table 1.

Population and sample

The sample group of the study consists of freshman architecture students enrolled at two universities in Türkiye offering architecture education. Quota sampling and convenience sampling methods were used to select these universities. Since the study population comprises freshman architecture students in Türkiye, the sample group was intentionally designed to include students from both public and private universities. Students from Mimar Sinan Fine Arts University (MSGSÜ), a state university, and Fatih Sultan Mehmet Vakıf University (FSMVU), a foundation university, were included, as these institutions provided easy access during the data collection phase. In total, 473 students participated in the study, with 261 from MSGSÜ and 212 from FSMVU. Of these, 264 students participated in both the pre-test and post-test.

Contents of the training semester

During the first semester, the core practical course was Technical Drawing, which introduced students to architectural projection techniques and required them to produce consistent plans, sections and elevations from given three-dimensional configurations using parallel projection. In the final assignment, students derived section and elevation drawings from a provided building plan. Throughout the semester, some weekly exercises also introduced basic three-dimensional digital modelling of geometric shapes using SketchUp. A separate elective perspective course further trained students to construct three-dimensional views on the two-dimensional drawing surface, including the determination of observer position, picture plane and cast shadows. In addition, the basic design course focused on fundamental spatial concepts (point, line, plane, volume, form, colour, texture) through two- and three-dimensional abstract compositions developed by hand drawing and small physical models. On the other hand, a theoretical "Introduction to architecture" course and other first-semester electives provided conceptual background. Together, these technical drawing, perspective and basic design activities engaged

Table 1. The methodological structure of the research

HYPOTHESES	METHOD	DATA COLLECTION	INDEPENDENT VARIABLE	DEPENDENT VARIABLE	ANALYSIS - TEST TECHNIQUE
Hypothesis 1: Architectural education will positively influence the development of spatial abilities.	Correlational method	Spatial Ability Test	One Semester Architectural Education	Spatial Ability	paired samples t-test
Hypothesis 2: The spatial ability levels of students, who begin with different levels of spatial ability, will converge by the end of one semester of education.					Correlation Analysis

Source: Authors

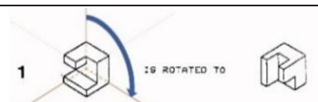
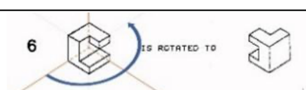
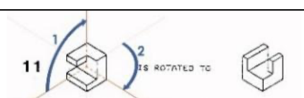
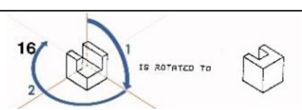
students in intensive work with two- and three-dimensional representations and required mental operations such as mentally rotating, reorienting and decomposing objects, which are closely related to the spatial abilities assessed in this study.

Data collection tools

To measure the spatial abilities of students, relevant measurement tools from the literature were reviewed. Various tests on this subject have been developed by different researchers (Sezen Yüksel & Bülbül, 2014). In this study, the ROT (The Purdue Visualization of Rotations Test), which is widely used in fields such as mathematics, engineering, educational sciences, and architecture, was employed. The responses given by the participants to the test questions were analyzed using analytical methods to confirm its validity in measurement. According to Bodner and Guay (1997) two primary processing strategies are used to solve spatial tasks: analytical processing and gestalt processing. Gestalt processing occurs when an individual creates and transforms visual images as a unified whole, whereas analytical processing involves breaking the whole into individual parts and analyzing the relationships between these parts. It has been suggested that the ROT test is less likely to be influenced by analytical processing compared to similar tests in the literature (Bodner & Guay, 1997).

The ROT test applied to the students consists of 20 questions, with a time limit of 10 minutes, as specified in Bodner's instructions. The difficulty level of the questions increases every five questions. Therefore, a new formula has been developed to obtain more reliable results when evaluating the test. In this method, the questions are classified according to their difficulty levels, and a new scoring system has been introduced. All questions in the test ask participants to determine the final image of a given three-dimensional object that is rotated in specific directions. However, the type of operation in each question varies. In this study, the types of operations in the questions were analyzed, and each question's score was determined based on the number of operations required. Table 2 presents the questions, operation types, and the corresponding scores for each question.

Table 2. Analysis of ROT questions and scoring technique

Question No	Question Examples with Operation Types Shown	Operation	Point
1 - 5		One direction 90°	1
6 - 10		One direction 180°	1,5
11 - 15		Two directions, both 90°	2
16 - 20		Two directions, one 90°, the other 180°	2,5

Source: The images in the table are adapted from Bodner & Guay with additional content. The table was prepared by the authors

Using this method, students received higher scores for more difficult questions based on their respective difficulty levels. The total score a student can obtain from the test ranges from 0 to 35. To evaluate the psychometric properties of this modified scoring, internal consistency of the 20 ROT items was examined, yielding acceptable reliability (Cronbach's alpha = .704 for the pre-test and .729 for the post-test). Moreover, the weighted total score was found to be almost perfectly correlated with the standard ROT total score at both measurement occasions (pre-test: $r = .987$, $p < .001$; post-test: $r = .975$, $p < .001$), indicating that the modified scoring preserves the construct measured by the original scoring while providing a finer differentiation across difficulty levels.

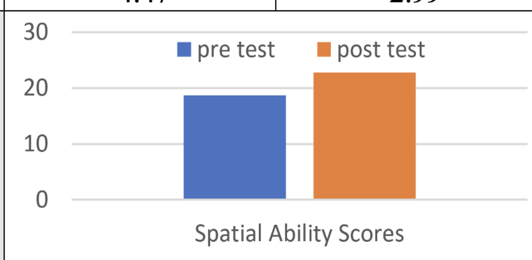
Results

To test the effect of architectural education on the development of spatial abilities (Hypothesis 1), the pre-test and post-test results administered to students before and after the education were compared. Since the same group of students was tested at two different time points, a paired samples t-test was used for this comparison. As shown in Table 3, the average score of 18.7 on the spatial ability test at the beginning of architectural education increased to 22.8 after one semester of education. According to the results obtained, there is a statistically very high level of significant difference between the pre-test and the post-test. (μPre-test=18.83, μPost-test=22.56, $p<.001$, $d=0.61$, 95% CI=2.99, 4.47). This finding demonstrates a significant improvement in the spatial abilities of students who completed one semester of architecture education. Therefore, Hypothesis 1 is confirmed.

To test Hypothesis 2, the study investigated how the difference between students with varying levels of spatial ability at the beginning of the course changed after one semester of education. For this purpose, the difference between the students' pre-test and post-test scores was calculated to determine the numerical contribution of the education to their spatial ability. Subsequently, the correlation between the scores obtained from the pre-test and the difference values mentioned above was calculated.

As shown in Table 4 (see next page), there is a negative correlation ($r = -0.518$) between the pre-test scores at the beginning of the course and the improvement (difference) values. This finding indicates that students with lower initial scores demonstrated greater improvement compared to those with higher initial scores and the result indicates a high level of significance ($r=-.518$, $p<.001$, 95% CI=.593, .429). In other words, the disparity between students with different levels of spatial ability at the outset decreased after one semester of education.

Table 3. Testing hypothesis 1

	Mean	Diff	N	Std. Deviation	p	95% Confidence Interval of the Difference	
						Lower -4.47	Upper -2.99
Pre-test	18.70	3.72	264	7.98	.000		
Post - test	22.80		264	7.07			

Source: Authors

Table 4. Correlation between pre-test scores and improvement values

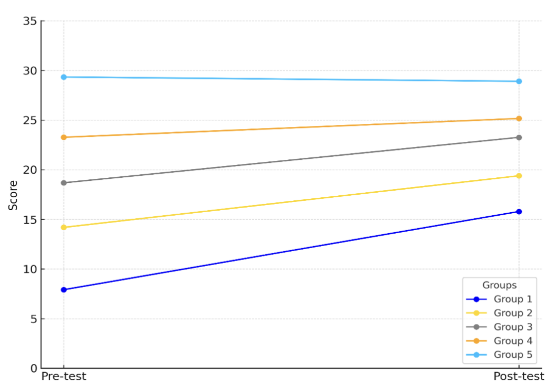
<table>
<tr><td colspan="2"></td><td>Pre-test – Improvement Values</td><td colspan="2">p</td></tr>
<tr><td rowspan="3">Pre-test</td><td>Pearson Correlation</td><td>-0,518</td><td colspan="2">0,000</td></tr>
<tr><td>Sig. (2-tailed)</td><td>,000</td><td colspan="2">95% Confidence Interval of the Difference</td></tr>
<tr><td>N</td><td>264</td><td>Lower
-.593</td><td>Upper
-.429</td></tr>
</table>

Source: Authors

According to statistics, the expressions of "very high level of significance" used for both hypotheses can be explained as follows. The p (probability) and Sig. (significance) values in the statistical tables indicate the level of statistical significance of the results. The equivalents of p according to the values it takes are as follows; "$p<0.001$ very high level of statistical significance; $0.001<=p<0.01$ high level of statistical significance; $0.01<=p<0.05$ statistical significance; $0.05<=p<0.10$ significance trend (borderline significance); $p>0.10$ difference is due to chance, no statistically significant difference was detected" (Kul, 2014).

Hypothesis 2 was reassessed using a second technique. In this method, students were divided into five groups based on their pre-test results, ranked from the highest to the lowest averages. The difference between the group averages in the pre-test and the post-test was analyzed, and the results were visualized as shown below.

Figure 1. Visualization of the increase between pre-test and post-test scores by achievement groups



Source: Authors

A total of 264 students who participated in both tests were divided into five groups, with the first four groups consisting of 53 students each and the last group comprising 52 students. The students within these groups were kept constant, and the averages of the groups in the pre-test and post-test were compared. The averages for the pre-test are shown on the left side of the figure above, while the averages for the post-test are shown on the right side.

As seen in the Figure 1, the performance ranking among the groups remained consistent; however, the gap between them narrowed. Based on this result, it can be stated that the first-year education in architecture not only improves spatial abilities but also helps students with different initial levels of spatial ability become more aligned with each other. These findings further validate Hypothesis 2.

Discussion and conclusion

This study investigated the impact of architectural education on the development of spatial abilities. In the literature, it is observed that most studies on spatial abilities are conducted in the fields of mathematics and engineering, while this subject has received relatively little attention in the field of architecture. However, abilities such as visualizing, rotating, and manipulating objects in the mind, as well as expressing these objects in two-dimensional planes, are crucial for both architectural education and practice. Scientifically investigating these skills, defined as spatial abilities, within the field of architecture is essential for ensuring that architectural education and practices can adapt to contemporary advancements.

This study revealed that architectural education enhances spatial abilities, with students demonstrating collective improvement in these skills after one semester of education. Additionally, it was observed that students with initially weaker spatial abilities showed greater improvement compared to those with stronger abilities, leading to a reduction in the disparity between them.

The findings of this study, which demonstrate the contribution of architectural education to the development of spatial abilities, align with previous studies in the literature. Türkmenoğlu Berkan and colleagues (2020) highlighted the contribution of the "Architectural Presentation Techniques" course to the development of spatial abilities. Berkowitz et al. (2021) compared the spatial abilities of undergraduate and graduate-level architecture students, demonstrating the impact of architectural education on the enhancement of spatial skills. Sutton and Williams (2011) noted that technical courses in architectural education improve spatial abilities. Additionally, they examined the spatial ability development of students in architecture and construction management programs, showing that architecture students who took design-based courses exhibited greater improvement. Türkmen (2022) revealed the contribution of the Basic Design course to the development of spatial abilities.

Beyond conventional studio and drawing courses, recent work has explored a variety of instructional formats that target spatial development in architecture and related design fields. Huamán et al. (2023) reported that a quasi-experimental intervention using Revit-based modelling led to significantly higher post-test scores on a spatial intelligence questionnaire among architecture students, compared to a control group following traditional instruction, suggesting that BIM-supported 3D modelling can strengthen spatial relationships, spatial visualisation and graphic representation. Gómez-Tone et al. (2021) found that immersive virtual-reality training, in which architecture students produced full-scale freehand sketches of architectural spaces inside a head-mounted display environment, produced significant gains in spatial orientation, mental rotation and visualization, while realistic VR walk-throughs allowed students to experience the intended spatial sensations of the designed environments. Köymen and Bouidani (2025), working with architecture and interior architecture students, showed that physical LEGO modules were particularly effective in fostering hands-on three-dimensional reasoning and confidence, whereas virtual LEGO tools enhanced digital spatial visualization and a sense of achievement; together these findings highlight that both analogue and digital, game-based construction tasks can support the development of spatial thinking in architectural education.

Taken together, these studies converge with the present findings in indicating that architectural education is associated with measurable improvements in students' spatial performance, even over relatively short instructional periods. Courses such as Architectural Presentation Techniques, technical drawing, and Basic Design have been shown to enhance spatial visualization, perception and orientation, as well as students' ability to interpret complex configurations and cross-sections, supporting the idea that studio- and representation-based curricula systematically cultivate spatial thinking. More recent work using BIM tools, immersive virtual-reality sketching, and LEGO-based construction tasks similarly reports gains in spatial relationships, visualization, and orientation, and highlights that both analogue and digital design environments can effectively foster spatial ability in architecture students. Within this broader body of evidence, the current study adds that even a single foundational semester centred on technical drawing, perspective and basic design can yield statistically significant improvements in mental rotation as measured by the ROT.

On the other hand, the results of this study differ from other studies demonstrating the role of architectural education in developing spatial abilities, specifically regarding the components of spatial ability. Türkmenoğlu Berkan and colleagues (2020) stated that architectural education leads to improvements in spatial visualization, spatial perception, and spatial orientation factors but does not result in significant improvements in mental rotation or spatial relational factors. Similarly, Berkowitz et al. (2021) found that graduate students outperformed first-year undergraduate students in tests involving mental cutting, perspective-taking, and establishing part-whole relationships, but no significant improvement was observed in mental rotation tests. In contrast, this study measured spatial abilities using a mental rotation test and, unlike the previous two studies, revealed that mental rotation skills improved significantly in parallel with architectural education.

The concept of spatial ability represents a broad spectrum of mental activities. Like all psychometric tests, the "Purdue Visualization of Rotations (ROT) Test" used in this study is a limited measurement tool, as it cannot be isolated from other intrinsic and environmental factors. However, since the sample size was sufficiently large, statistically significant results were achieved. On the other hand, it should be noted that the ROT is a mental rotation test and therefore captures only one component of the broader construct of spatial ability, rather than the full spectrum of spatial skills. At the same time, several methodological limitations need to be considered. A concern relates to potential test–retest or practice effects, given that the same version of the ROT was administered twice; practice effects are typically strongest at short retest intervals (around one month) and are reported to diminish when the interval extends to 1–3 years (Pezzuti et al., 2022), so the five-month interval used in this study likely reduces, but does not eliminate the influence of repeated testing on the observed gains. Moreover, because a single-group pre–post design without a control or comparison group was employed, natural maturation and other experiences over the semester may also have contributed to changes in spatial scores, and the larger improvements among students with lower initial scores may partly reflect regression to the mean rather than educational effects alone. Finally, pre–post analyses were conducted only with the subgroup of students who completed both test administrations (n = 264); while this is appropriate for paired designs, the findings most directly apply to this subgroup, and possible differences between students who did and did not complete both tests cannot be examined with the available data.

From a pedagogical perspective, these findings suggest that even a single foundational semester centred on technical drawing, perspective and basic design can be intentionally structured to foster measurable gains in students' spatial abilities, particularly mental rotation. At the studio-curriculum level, this supports the integration of tasks that require frequent switching between 2D and 3D representations (e.g., orthographic, axonometric, perspective transformations, physical and digital model making, VR or BIM supported visualisation), so that spatial reasoning is treated as an explicit learning objective rather than a side-effect of design work. For students who enter with lower initial spatial scores, it may be beneficial to incorporate targeted scaffolds such as short, structured mental-rotation exercises at the start of studio, game-based construction activities (e.g., LEGO type assemblies) and additional feedback on spatial representation tasks; our results indicate that such students have the potential to improve the most over time, provided that the curriculum offers sustained, progressively challenging opportunities to practise spatial thinking.

As a result, it has been observed that architectural education makes a significant contribution to the development of spatial abilities. Moreover, an educational program aimed at developing spatial abilities not only enables individuals at different levels to show a collective improvement but also fosters greater development in those at lower levels, bringing them closer to those at higher levels. Based on this, it can be said that the challenges initially faced by students enrolling in architecture departments at universities in understanding three-dimensional concepts will decrease through education. Additionally, it appears that with the right pedagogical program, educators can bring students at various levels to a level that meets the mental competencies required by the education. C

Bibliographic references

Berkowitz, M., Emo, B., Gerber, A., Hoelscher, C., Kurath, S., & Stern, E. (2018), "Development of a novel test to measure spatial abilities of architecture students: Preliminary findings", presented at the 7th International Conference on Spatial Cognition (ICSC 2018), Rome, Italy, 10–14 September 2018.

Bodner, George M.; Guay, Roland B. (1997), “The Purdue visualization of rotations test”, *The Chemical Educator*, Vol. 2, núm. 4, pp. 1–17. DOI: 10.1007/s00897970138a.

Galton, Francis (2004), *Inquiries into Human Faculty and Its Development.* London, J. M. Dent & Sons.

Gardner, Howard (2011), *Frames of Mind: The Theory of Multiple Intelligences.* New York, Basic Books.

Gómez-Tone, H. C., Martin-Gutierrez, J., Bustamante-Escapa, J., & Bustamante-Escapa, P. (2021). Spatial skills and perceptions of space: Representing 2D drawings as 3D drawings inside immersive virtual reality. *Applied Sciences,* Vol. 11, num. 4, pp. 1475.

Guay, R.; McDaniel, E.; Angelo, S. (1978), "Analytic factor confounding spatial ability measurement", paper presented at the Annual Meeting of the American Psychological Association, Toronto, Ontario, Canada.

Huamán, Y. T., Santivañez de Osambela, J. E., & Farfán Pimentel, J. F. (2023). Application of Revit software to improve spatial intelligence in architecture students in a private university – Huancayo. *International Journal of Professional Business Review,* Vol. 8, num. 10, pp. 01-22.

Hoffman, Moshe; Gneezy, Uri; List, John A. (2011), “Nurture affects gender differences in spatial abilities”, *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 108, núm. 36, pp. 14786–14788. DOI: 10.1073/pnas.1015182108

Kozhevnikov, Maria; Kosslyn, Stephen; Shephard, Jennifer (2005), "Spatial versus object visualizers: A new characterization of visual cognitive style", *Memory & Cognition*, Vol. 33, núm. 4, pp. 710–726. DOI: 10.3758/BF03195337

Köymen, E., & Bouidani, M. F. (2025). Analytical comparison of physical and virtual LEGO modules in architectural design education. *Journal of Design for Resilience in Architecture & Planning*, Vol. 6, Issue 3, pp. 526–537.

Kul, Seval (2014), “İstatistik sonuçlarının yorumu: p değeri ve güven aralığı nedir?”, *Plevra Bülteni*, Vol. 8, núm. 1, pp. 11–13. DOI: 10.5152/pb.2014.003

Linn, M. C.; Petersen, A. C. (1985), “Emergence and characterization of sex differences in spatial ability: a meta-analysis”, *Child Development*, Vol. 56, núm. 6, pp. 1479–1498. DOI: 10.1111/j.1467-8624.1985.tb00213.x

Lohman, David F. (1979), *Spatial ability: A review and re-analysis of the correlational literature (Technical Report No. 8).* Aptitudes Research Project, School of Education, Stanford University.

Mayer, Richard E.; Sims, Valerie K. (1994), “For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning”, *Journal of Educational Psychology*, Vol. 86, núm. 3, pp. 389–401. DOI: 10.1037/0022-0663.86.3.389

McGee, Mark G. (1979), *Human spatial abilities: Sources of sex differences.* New York, Praeger.

Turkish Ministry of Education (2020), "Öğretim programları", [Electronic resource], disponible en: http://mufredat.meb.gov.tr/Programlar.aspx [17 de agosto de 2025].

Mohler, James L. (2006), *Examining the spatial ability phenomenon from the student’s perspective.* (Unpublished doctoral dissertation). Purdue University.

Nassar, Khaled; Mostafa, Magda; Rifki, Amr (2010), “Visualization skills for the new architectural forms”, *ArchNet-IJAR*, Vol. 4, núm. 2/3, pp. 346–358.

Sağıroğlu, Pınar Meliha (2017), “Mimari Tasarım Eğitiminde Çoklu Zeka Kuramından, Lefebre’nin Üçlü Mekan Diyalektiğine Uzanan Bir Öğrenme Deneyimi: Mekan Oyunları”, *Megaron*, Vol. 12, núm. 1, pp. 78–86. DOI: 10.5505/megaron.2016.76768

Pezzuti, Lina; Dawe James and Lauriola, Marco. (2022). Threshold values for significant changes in test-retest difference scores for the Wechsler Intelligence Scale for Children – Fourth Edition., *Bollettino di Psıcologia Applicata*. Vol. 2022, num. 294 pp. 14-27. *https://dx.doi.org/10.26387/bpa.2022.00004*

Sezen Yüksel, Nazan; Bülbül, Ali (2014), “Uzamsal görselleştirme üzerine test geliştirme çalışması”, *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, Vol. 8, núm. 2, pp. 124–142. DOI: 10.17522/nefefmed.32631

Sorby, Sheryl A. (1999), “Developing 3-D spatial visualization skills”, *Engineering Design Graphics Journal*, Vol. 63, núm. 2, pp. 21–32. DOI: 10.18260/edgj.v63i2.126

Spearman, C. (1927), *The abilities of man: Their nature and measurement*, New York, The Macmillan Company.

Sutton, K.; Williams, A. (2011), “Spatial ability and its implication for novice architecture students”, in 45th Annual Conference of the Architectural Science Association, The University of Sydney, Australia.

Thurstone, L. (1973), “Primary mental abilities”, in *The measurement of intelligence*, pp. 131-136, New York, Springer.

Thorndike, Edward L. (1921), “On the organization of the intellect”, *Psychological Review*, Vol. 28, num. 2, pp. 141–151.

Towle, E., Mann, J., Kinsey, B., O’Brien, E., Bauer, F., & Champoux, R. (2005). Assessing the self efficacy and spatial ability of engineering students from multiple disciplines. In 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis.

Türkmenoğlu Berkan, S., Karaman Öztaş, S., Kara, F. İ., & Engin Vardar, A. (2020), “The role of spatial ability on architecture education”, *Design and Technology Education: An International Journal*, Vol. 25, num. 3, pp. 103–126.

Türkmen, Anday. (2022). Temel Tasarım Eğitiminde Çoklu Zekâ Kuramı Üzerinden Uzamsal Becerinin Gelişimine Etki Eden Bir İzlence Önerisi. (Unpublished doctoral dissertation). Mimar Sinan Fine Arts University.

Yağmur Kilimci, Elif Sezen. (2010). 3D Mental Visualization in Architectural Design. (Unpublished doctoral dissertation). Georgia Institute of Technology.