International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 1, February 2025, pp. 260~268
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i1.30911

The effects of design-based art activities on students' spatial thinking skills

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Article Info

Article history:

Received Apr 21, 2024
Revised Sep 26, 2024
Accepted Oct 5, 2024

Keywords:

Architecture
Art education
Basic design
Design-based learning
Spatial thinking

ABSTRACT

This study was conducted to determine the effects of design-based learning (DBL) on students' spatial thinking skills in architectural design education. Spatial thinking skills are of great importance in the architectural design process for architecture students to perceive and comprehend both the surrounding architectural spaces and the architectural product they design from different dimensions and perspectives. In order to gain this skill, DBL approaches based on a cooperative learning approach, which allow students to actively participate in the learning process, were applied. It was tested whether the DBL approach would increase students' spatial thinking skills and develop skills, such as visual structuring skills, creativity, multidimensional and abstract thinking skills, imagination, problem solving, and multi-function execution. The research model is a pre-test-post-test control group quasi-experimental design. Data were obtained using the spatial thinking skills test. Based on the findings obtained as a result of the research, it was determined that the DBL approach applied in the color and texture course was effective on the spatial thinking skills of 2nd-year architecture students.

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1. INTRODUCTION

Societies increasingly need radical changes in their education in order to raise individuals who are equipped with the qualified skills needed to keep up with science and technology in the 21st century, such as problem solving, creative thinking, critical thinking, cooperation, communication, and innovation. Changes in accordance with the age are inevitable in architectural education, which is the art and science of designing and constructing structures and the physical environment. This research aims to determine the level of awareness about this among students who have just started their architectural education. To achieve higher levels of spatial literacy, there is a need for educational processes that will help architecture undergraduate educators design tools that encourage advanced problem solving in a wide variety of social science fields.

Architecture, the essence of which is architectural design; gains vitality and reality through the human operations and lives in these spaces, which are shaped according to people's dreams and fictionalized at different scales; These space also contain aesthetic, social, cultural, historical, production, political and economic contexts and meanings, values and systems that are the whole [1]. One of the concepts discussed in the definitions of the architecture department is that spatial thinking is complex. Spatial thinking skills can be expressed as people's ability to associate any data or information with a space, both consciously and unconsciously in order to fulfill various ways of daily survival and produce solutions to problems [2].

An important acquisition for the architecture department is the ability to comprehend spatial relations. Experiencing spaces and meetings, acquiring and observing information in the accompanying place, making comparisons, questioning, trying to enter situations and environments from different angles are all essential to architectural education and the execution of the profession [3]. Skills involved include recognizing spatial distribution and patterns in the world, connecting with location, preserving and constructing phenomena that indicate spatial distribution, using spatial units and seconds, frame-of-reference, imagining verbal explanations on the map, drawing a total map, map completion, and superimposing and melting on the map [4]. Gänshirt [5] argues that architectural research should develop approaches that draw from various disciplines and sociocultural contexts as these inform the nature of knowledge. This knowledge includes information from natural sciences, social sciences, humanities, and artistic pursuits. However, regardless of the differences in design teaching methods in architectural education, Kowaltowski *et al.* [6] determined that acquiring knowledge is usually achieved through "learning by doing". In this method, students are expected to gain an understanding of design and the design process through traditional workshop practices, where they are in a passive position rather than being taught formally. Design studio trainers usually use guidelines they have applied and have experience with [7].

The architecture curriculum generally consists of core courses that develop design knowledge: technology-based courses that develop the scientific foundation of architecture, artistic based courses to strengthen architectural expression and design courses that combine all three [8]. Alnusairat *et al.* [9] emphasized that the design studio, where design courses are given, is a unique environment with distinct pedagogical, sociological, ideological and epistemological aspects, and thus the active participation of students in these spaces is of great importance for the permanence of knowledge. It is expected that the use of design-based learning (DBL) processes, which enable students to actively participate in the learning process through the cooperation between researchers and practitioners, will provide solutions to the problems encountered in this respect. First introduced to the literature by Collins and Brown in the early 90s and referred to as "design experiments". Akker later suggested that it be called "developmental research" as a research method [10], the most common names fort his approach are: design experiments [11], [12], design research design-based research, and developmental research [10], [13]. Design-based research is briefly defined as the synthesis of designing and developing solutions for practical problems in learning environments a long with reporting reusable design principles [14]. McKenney and Reeves [15] stated that research that produces innovations and continues their development has begun to be called 'design research'. When examining the most common and main features in design-based research definitions a general definition emerges it is a systematic yet flexible methodology that aims to improve educational practice through iterative analysis, design, development, and implementation based on collaboration between researchers and practitioners in real-world settings, leading to context-sensitive design principles and theories [16].

Additionally, design-based research is an interdisciplinary mixed research approach [17]. In the relevant literature reviews, there are studies showing that DBL is especially suitable for helping engineering students acquire basic competencies and become active participants in solving daily engineering problems [18]. It has also been suggested that DBL has a positive effect on different types of skills such as design, scientific process, cognitive, and problem solving skills [19]. Moreover, studies have demonstrated that DBL increases cooperation and communication among students as it encourages teamwork [20], [21]. Additionally, there are studies suggesting that DBL is a sustainable learning environment for finding solutions to social problems [22]. Furthermore it has been observed that in the applications of DBL, the desired design task has a motivating effect on the participants which improve in attitude, and facilitates learning [23].

Spatial thinking skills are of great importance in the architectural design process for the architectural student to perceive and comprehend both the architectural spaces around him/her and the architectural product he/she designs with different dimensions and perspectives. In studies with two and three dimensional representation tools such as drawings, models, digital models, different views and situations are obtained by rotating objects within a fixed viewing angle. Perspective drawings, virtual-enhanced-mixed reality environments or three-dimensional photorealistic visuals, on the other hand, take into consideration the possible orientations of the designer and/or potential users and accordingly different perception possibilities. Architect candidates are expected to be able to manage a process that constantly moves between perceptual space, imaginary space and representational space within the framework of artistic sensitivity and technical knowledge. The architectural design studio, in particular, involves a series of spatial design problems of increasing parameters and complexity. These problems can be defined as cognitive tasks that require visual-spatial and visual structuring skills, creativity, multidimensional and abstract thinking skills, imagination, problem solving and multifunctional skills. Students are asked to transfer the strategy, method or approach they have used, developed and learned while performing design tasks to the next task. This requires both advanced cognitive functions and metacognitive awareness.

In this systematic, which is based on the cooperation of all senses, physical strength, and imagination, the role of cognitive organization is a curious element. At this stage, the examination of the visual-spatial processes of architecture students gains importance. In this research conducted in line with this understanding, priority was given to activities such as obtaining on-site information about spaces and observing, making comparisons, questioning, and trying to look at problems from different perspectives in the design practices carried out by the students of the department of architecture to better understand spatial relations. In the study, we tested whether the students could develop skills such as visual structuring skills, creativity, multidimensional and abstract thinking, imagination, problem-solving, and multitasking, which are necessary to increase their spatial thinking skills, with the DBL approach. This research differs from other studies that limit students' spatial thinking skills only to the expansion or interpretation of spatial data, in that it allows students to prepare and present projects that reveal their spatial knowledge [24]–[26]. This situation clearly reveals the importance of the research. The fact that the activities were carried out in line with the design-based approach is also a different application from other studies [27], [28].

In the literature review, we conducted during the research process, we saw a large gap in the field of art and design regarding design-based applications. In this research conducted to fill this gap, activities were carried out with the DBL approach, which aims to plan and develop new environments or new theories in teaching and learning. These activities were carried out with the DBL approach, which aims to plan and develop new environments or new theories in teaching-learning. Therefore, it is thought that the implementation of this research in the art practices course of the students of the department of architecture is suitable for the purposes of DBL. In light of these issues, it is hoped that the findings of the research can be used as a basis for further research on innovative learning models and strategies that can develop cognitive abilities and spatial thinking skills in architecture students.

2. METHOD

This study, which aimed to determine the effect of the DBL approach applied in the elective color texture courses on the spatial thinking skills of architecture candidates in the 2nd year, used a quasi-experimental design with pretest-posttest control group. This design was chosen for two main reasons; it increases the statistical power associated with the experiment by reducing the error term due to measurements made on the same subjects, and it requires fewer subjects, thus saving time and effort. Subjects were divided into two groups through unbiased selection from the pool of (architecture 2nd year students, with one group chosen as the control and the other as the experimental group. The pretest measurement of the dependent variable (spatial thinking skills) was collected from the subjects in both groups at the beginning of the experiment. The control group, received teaching by presentation, while the experimental group, received the independent variable, DBL applications. The researcher supervised the process in both groups. It was deemed effective to use architecture candidates as the sample of the research, since it is thought that their spatial thinking skills will contribute positively to their professional self-efficacy levels and recognizing spatial dimensions in architecture is a skill intended to be gained by the students in line with the educational program's objectives.

2.1. Working group

The study group for the research consisted of a total of 26 students who took the color and texture course during in the 2nd year of Manisa Celal Bayar University, Faculty of Fine Arts, Design and Architecture, Department of Architecture in the fall semester of the 2022-2023 academic year. An easy sampling method was preferred for the study. Descriptive information about the students who participated in the research based on the volunteers of the researchers is shown in Table 1.

Table 1. Distribution of demographic information on the study group

Gender	n	%
Female	18	69
Male	8	31
Total	26	100

Whether the pre-test scores of the experimental group and the control group will differ or not regarding the effect of DBL on the students' spatial thinking skills was determined with the t-test. According to the classification of Cohen [29] with the t-test approach, at least 21 participants are needed to detect a medium effect. Therefore, the number of samples in this study is sufficient. In the research, the convenience sampling method, which is one of the non-random sampling methods, was used. With the convenience sampling method, the researcher can include the people in the sample by using their close circle, acquaintances or easily accessible tools.

2.2. Data collection tool

The spatial thinking ability test (STAT) developed by Lee and Bednarz [4] was used to determine the effect of the color and texture course given to the students of the architecture department with a DBL approach on their spatial thinking skills. This test is a series of multiple-choice questions designed to assess students' skills, including overlaying and solving a map, reading a topographical map, evaluating various factors to find the best location, recognizing spatially related phenomena, creating point-based isolates, and performance tasks. The test was originally designed to assess the development of individual Geography teachers working in the USA in their spatial thinking skills. Since it has been understood by other researchers that it is a data set that allows for providing a preliminary assessment of the reliability and validity of spatial thinking conceptualizations, it has started to be used frequently in other fields.

The first step in creating the revised and expanded spatial skill test was to define the assessment objective and describe the test contents to be measured. Two sets of spatial thinking concepts were analyzed and combined to inform the development of STAT. The theoretical foundations of the first set of concepts were taken from the work of Gersmehl [30]. The second set consisted of Golledge's spatial thinking skills list, which played an important role in the development of the original STAT [31]. Golledge's concepts were sufficiently detailed to develop test items, potentially leading to improved validity of test content. Additionally, both lists share some common concepts and features. Each test item was designed to measure one or two components of spatial thinking identified by one or both of these two studies. Aspects of spatial thinking skills covered by STAT include: grasping orientation and direction, comparing map information with graphic information, choosing the best location based on several spatial factors, imagining a slope profile based on a topographic map, relate spatially distributed phenomena, mental visualization of 3D images based on 2D information, overlaying and dissolving maps, and grasping geographic features represented as points, lines, or polygons.

2.3. Research process

In accordance with the design research learning data, the researcher conducted the research with the people involved in the experimental research. He designed and implemented interventions as implementer systems, reviewed the initial design based on the results of the practice, developed and re-applied it, and continued this research process cyclically until it was concluded that the structured execution had developed adequately due to the organic nature of DBL. DBL, which renews itself according to the situation, differs from traditional design methods in this respect

2.4. Structural applications in public space

In this activity, it is aimed to make a structural design by using concepts such as balance, rhythm, contrast (which are design principles of art education), and color, texture, movement, value, space, ratio, and proportion (which are design elements). It is emphasized that the uniquely formed connections between these elements and principles of design constitute the composition and that it is not necessary to use all elements and principles of design together in a composition. What is required is the establishment of appropriate connections and the formation of a solid integrity. In the next process, students were asked to make applications on the structure of paper, cardboard, plastic/wooden sticks, which were carried out with a plug-in system. Considering the current conditions for the city center of the city of Manisa, located in the Aegean region in the west of Türkiye, it has been stated in the directives that a structure which will stand alone by intertwining in the form of a cross-over system with horizontal and vertical two elements, should be created in a public space. At this stage, it is focused on issues such as determining the purpose and where the structure work will be done by brainstorming. In addition, they were asked to prepare designs that would enable the space occupied by the form to be perceived strongly in the public space, using the design principles and elements. The design process started with a theoretical presentation of the researcher that included definitions given to the students and various examples.

In the following process, they were directed to realize the criteria and limitations for the solution of the problem, to make different experiments for the solution and to constantly test these solutions, and to find solutions to the problem by making different designs when they encounter a problem. The students were asked to identify the strengths and weaknesses of the designs they presented at the end of the process. For this reason, peer assessment was carried out in order to develop high-level thinking skills and to enable them to actively participate in the assessment process.

2.5. Analysis of data

In the process of analyzing the data, the assumptions of the parametric tests were checked to see if they were met: "the data should be intermittent or proportional", "the data should comply with the normal distribution" and "group variances should be equal". The Shapiro-Wilk normality test and Kurtosis-Skewness values were examined to determine whether the scores obtained from the data collection tools of the students in the experimental and control groups had a normal distribution. After it was determined that the basic assumptions regarding the analysis of covariance were met, a t-test was conducted to see if the pre-test scores of the experimental group and the control group differed regarding the effect of DBL on students' STAT. The arithmetic averages of the post-test scores corrected in accordance with the pre-test scores of the experimental group and the control group were taken, and covariance analysis was performed to see if the difference between the mean scores of the post-test scores in the groups was significant.

3. RESULTS

In this section of the study, in order to investigate the effect of DBL on students' spatial thinking skills, analyses were conducted to determine the effect of independent variables on dependent variables in terms of the procedures applied in the experimental and control groups. The dependent variables of the study for the purpose of the study are: visual structuring skills, creativity, multidimensional and abstract thinking skills, imagination, problem solving and multi-tasking. The independent variable whose effect on these dependent variables is examined is spatial thinking skills.

3.1. Examination of the effect of DBL on students' spatial thinking skills

To investigate the effect of DBL on students' spatial thinking skills, one factor analysis of covariance (ANCOVA) was applied to control for the effects of the pretest on the dependent variable. Before the analysis of covariance was put into practice, it was analyzed to determine if the criterion of congruence of regression slopes, which is among the basic conditions of the analysis, was met. The findings are given in Table 2.

Table 2. Regression slope of the data obtained from the spatial thinking skills scale

	Source	SD	df	MS	F	p-value
Spatial thinking skills	Corrected model	14788.322	3	311.329	5.320	.013
	Still	6476.455	1	6476.455	67.711	.000
	Group	614.366	1	614.366	7.770	.033
	Pre-test	37.640	1	37.640	.415	.832
	Group*Pre-test	311.489	1	311.489	4.311	.083
	Mistake	1145.432	24	93.122		
	Total	273730.000	26			
	Adjusted total	5000.000	25			

Note: SD= standard deviation, df=degrees of freedom, MS=mean square, F=frequency

When examining the findings in Table 3, it can be seen that the condition of equality of regression slopes, which is a requirement covariance analysis, is fulfilled. For the regression slopes to be congruent, the p values in the Group*Pre-test row must be insignificant ($p>.05$). The regression slopes of the spatial thinking skills scale were matched and the condition for covariance analysis was met ($F=4.311$, $p>.05$). Having determined that the basic assumptions for the analysis of covariance were met, it was then determined whether the pre-test scores of the experimental group and the control group would differ with respect to the effect of DBL on the spatial thinking skills of the students. The results of the analysis are given in Table 3.

The degrees of freedom, mean scores, t-test analysis, and standard deviation results of the spatial thinking skills scale pre-test scores of the control and experimental groups are given in Table 3. It was observed that there was no significant difference in the results of the t-test analysis regarding whether there was a difference between the groups according to the pre-test results ($t(24)=-.322$, $p>0.05$). The post-test scores corrected in accordance with the pre-test scores of the experimental group and the control group are presented in Table 4.

Table 3. T-test analysis results of experimental and control groups according to pre-test scores

Group	n	$\bar{x}$	SD	df	T-test	p-value
Control group pre-test	13	102.12	14.25	24	-.322	.848
Experimental group pre-test	13	110.52	16.01			

Note: n= sample, $\bar{x}$=mean, SD=standard deviation, df=degrees of freedom

Table 4. Post-test mean scores adjusted according to pre-test scores

	Group	n	$\bar{x}$	Adjusted avg.
Spatial thinking skills	Experiment	13	135.33	132.32
	Control	13	110.62	100.35

When examining the findings in Table 4, the post-test average score of the students regarding the STAT inventory is X=100.35 for the corrected averages in the control group, and X=132.32 for the experimental group's average points. When the scores obtained in the posttest and corrected mean scores of the STAT scale in general, it is seen that the posttest mean score in the experimental group is even higher than the posttest mean score in the control group. The results of the covariance analysis performed to determine whether the difference between the mean scores of the post-test scores in the groups is significant or not are given in Table 5.

Table 5. The results of covariance analysis in which the pre-test effect of the spatial thinking skills scale was kept under control

	Source	SD	df	MS	F	p-value	η^2
Spatial thinking skills	Corrected Model	965.125	3	547.127	5.029	.019	.422
	Still	7106.143	1	7106.143	73.138	.000	.825
	Pre-test	.415	1	.415	.023	.987	.000
	Group	989.112	1	989.112	9.409	.084	.652
	Mistake	1298.331	24	110.341			
	Total	273730.000	26				
	Adjusted Total	5000.000	25				

Note: SD= standard deviation, df=degrees of freedom, MS=mean square, F=frequency, η^2=number of observation values

When examining the results of the covariance analysis to determine if the difference observed between the post-test mean scores of the groups is significant, Table 5 shows the post-test scores corrected according to the pre-test scores between the groups ($F(1.19)=9.409$, $p=.086$, $\eta^2=.652$). It is clear that there is a significant difference in favor of the experimental group (X experiment=132.32, X control=100.35). This suggests that the attitudes of the experimental group towards DBS are high, as indicated by their high scores on the spatial thinking skills scale. The effect size value, which indicates the ratio of the variance explained by the independent variable of the dependent variable was calculated as $\eta^2=.652$. According to Cohen [29], this effect size value falls is in the category of $\eta^2=.257$ “large effect”.

4. DISCUSSION

In this study, the effectiveness of the application of DBL approaches in the color and texture course given in the architecture department in developing the spatial thinking skills of the students was investigated. The research questions were handled and the STAT scores of the students were analyzed. Within the scope of the research problem, “what is the effect of the courses conducted with DBL in the color and texture course on the spatial thinking skills of the students?” The answer to this question was sought. To this end, an experimental study was carried out based on program-based teaching practices in the Architecture 2nd grade color and texture course in the control group and on DBL in the experimental group. The STAT scale was used to measure the change and development in the spatial thinking skills of the experimental and control groups before and after the application. The findings from the research showed that there was a significant difference in the results of the covariance analysis regarding the difference observed between the post-test mean scores of the groups, and it was understood that this difference was in favor of the experimental group (X experiment=132.32, X control=100.35). Thus, it is seen that DBL is more effective on the spatial thinking skills of the students than the color and texture course taught with the traditional teaching method.

This study confirms the results of many previous studies that DBL facilitates students’ development of scientific understanding [32], [33]. The DBL approach was used in the development of spatial thinking as it is a teaching approach that encourages active student participation in the learning process. It encourages students to research, define the problem, develop ideas, make prototypes, and produce design solutions in order to solve a problem [20], [34], [35]. DBL not only gives students an interactive role in the learning process, DBL also contributes to their academic success by increasing their curiosity and motivation [24], [36], [37]. In the studies on DBL examined in the literature, it is also seen that DBL practices in the courses make significant contributions to the expectations of the students in the professional field [38], [39]. The results of the research in the literature support the results obtained in this study and reveal the importance of DBL practices in the acquisition of the spatial thinking skills that architectural students should have professionally before the profession. According to the results of the studies examining the spatial thinking characteristics with gender, class level, culture, physical environment, education, and the possible interactions between these variables in the literature, it is seen that they have positive effects on improving spatial growth [40]–[44]. Studies examining the relationship between spatial thinking and increasing the ability to solve complex problems have also shown that this has a similarly positive effect, contributing to the development of students' analytical, critical and creative thinking skills as well as their problem-solving skills. [32], [45], [46]. In addition, there are also studies suggesting that spatial education interventions potentially lead to the transfer of gains to other areas such as mathematics [47]. In conclusion, spatial thinking is an important mental skill that helps a person understand the world around them and use that understanding to solve problems and make decisions.

Although the results of this study were based solely on second-year architecture students who completed a conceptual scale, it is not appropriate to generalize the results to students in different classes or contexts. To support the results obtained in the research, further studies should be conducted in many different areas, especially to confirm the role that DBL can play in facilitating students' thinking skills and learning scientific concepts. Future research should also involve a larger student population; this may allow for comparison of the conceptual learning of scientific concepts among students with varying levels of design-oriented mindset in certain aspects. In addition to this quantitative research, qualitative research such as interviews can be conducted to gain more in-depth views of students on the DBL process. The importance of art education before and within architectural education and their possible contributions are, in this sense, invaluable.

5. CONCLUSION

It seems that DBL, in which the research results have been modified, is more effective on spatial thinking skills than the lessons taught with the traditional teaching method. It can be said that it is important to develop the spatial thinking skills of students in the architecture department as this will enable them to organize their thoughts and information according to spatial locations and relations. This type of thinking often involves solving problems or making decisions using spatial features such as the positions, directions, distances, and relationships of objects. For instance, when planning architectural designs, spatial thinking assists in the most efficient route planning, taking into account factors such as the destination, distance, and routes. Spatial thinking is also important in fields such as mathematics, engineering, architecture, and geography as it allows those working in these fields to analyze the information needed to design and build solutions. In Türkiye, the spatial cognition and visual spatial organization of the students enrolled in architecture departments are mainly discussed based on the experiences and observations of architectural educators and evaluated by their performance in the given designs. The findings of this study show that first-year architecture students perform in accordance with the developmental levels of their age groups when it comes to abstract thinking, visual perception, and comprehensive-logical skills. It would not be correct to conclude from the findings that more visually spatially developed candidates prefer architectural departments.

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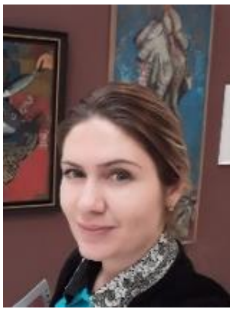

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