

CREATIVITY, THREE DIMENSIONAL VISUALIZATION ABILITY AND SUCCESS IN PRE-UNIVERSITY AND DESIGN EDUCATION

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Abstract

Educators and researchers in design based programs argue that a design student should be creatively active and have three-dimensional visualization ability. Yet, no study provides empirical evidence on whether such skills foster success in pre-university education and design based programs. Thus, this study aimed to empirically investigate the relation between creativity, three dimensional visualization ability, and achievement in pre-university and basic design education. For that end, the study introduced a methodology on how creativity and three dimensional visualization ability (for objects and spaces) could be measured. First grade students studying in the City and Regional Planning Department at Dokuz Eylul University volunteered to participate. Results showed that creativity and three-dimensional visualization abilities (for objects and spaces) did not affect success in pre-university education; however, three-dimensional visualization ability for objects affected success in basic design education. This study is important in describing a methodology to measure abstract concepts such as creativity and three dimensional visualization ability and bringing forth interesting future research areas such as testing whether such skills are necessary to become better designers or whether they could be improved with design education.

Keywords

Design education, visuaization, creativity

Introduction

Educators and researchers in design based programs, including architecture and city planning, argued that a design student should be creatively active (Denel, 1981) and have three-dimensional visualization ability (Gunay, 2007). However, there is little empirical evidence that can support these statements (Goldschmidt, 1994; Chun-Heng, 2006). This suggests a need for testing the relative importance of creativity and three dimensional visualization ability on academic achievement in design based programs in general, and basic design education in particular. Considering the fact that, students do not have to pass a visual / spatial capability and creativity tests to major in a design based program in many countries (1) (see Salama 2005 for details), the effect of creativity and visual/spatial thinking ability on success in pre-university education deserves to be investigated as well. Thus, this study aims to test the effect of creativity and three dimensional visualization

ability on success in pre-university and basic design education.

While creative ability is necessary for all spheres of life, it is especially important in design education (Casakin & Goldschmidt, 1999; Casakin, 2007; Cross, 1997; Cubukcu & Dundar, 2007; Potur & Barkul, 2006; Salama, 1995). Salama (1995) discussed the changing concept of creativity in design education. He argued that, earlier creativity was perceived as an innate gift which includes only the intrinsic influences. At that time, creativity in design education has been related to artistic quality of the physical form. Then later, it was acknowledged that creativity includes extrinsic influences; such as cultural, social and environmental influences. Moreover, other creative aspects of design, such as designing better environments for people and considering environmental-behavioral issues in design, has been recognized. Acknowledging the fact that design education should balance creativity in designing the physical form artistically and creativity in considering behavioral issues in design, this study focused on creativity in designing the physical form artistically.

Creativity is defined as the ability to produce as many novel and appropriate alternative solutions as possible for an ill-defined problem⁽²⁾ in a limited time (Denel, 1981; Malaga, 2000). Researchers have developed a number of tests to assess creativity (Puccio & Murdock, 1999). Most of these tests measured creativity in general. Only a limited number of studies suggest alternative tests to measure creativity in relation to design. Moore (1970) suggested eight tests to measure an architecture student's creativity. These were open ended, free response tests that focus on the number of 'correct' and 'appropriate'

ideas produced to solve an ill defined problem. Moore (1970) named and explained these tests as:

- “(1) SKETCHES: the ability to generate many visual patterns or images which conform to simple specifications,
- (2) ALTERNATE USES: the ability to generate a wide range of ideas spontaneously from a given idea,
- (3) MATCH PROBLEMS: the ability to generate many different solutions in response to a particular problem situation,
- (4,5) CONSEQUENCES: the ability to generate many elementary ideas appropriate to simple verbal requirements, and originality, and the ability to generate remotely associated, uncommon or clever ideas,
- (6) GESTALT TRANSFORMATIONS: the ability to shift the functions of an object or part of an object in order to use it in a new way,
- (7) HIDDEN FIGURES: the ability to give up one perceived organization of a visual pattern in order to see another,
- (8) FIGURE ANOLOGIES: the ability to recognize figural relationships between different forms.”(Moore, 1970; pp: 31)

Based on Moore's (1970) definitions, Denel (1981) provided examples for the sketching, alternate use, and consequences tests. We replicated those examples in this study to measure creativity. For the remaining tests, full examples were not provided. Thus, we developed new tests based on the explanations given in Moore (1970).

Three dimensional visual/ spatial thinking ability is defined as the ability to read, reason, and represent three-dimensional volumes and

spaces on two dimensional media, such as paper (Chun-Heng, 2006; Gunay, 2007). Visual / spatial thinking ability is crucially important for planners and architects as they are expected to think about three dimensional space and represent their ideas visually on two dimensional media (Goldschmidt and Smolkov, 2006). There has been wide spread research on visual / spatial thinking ability (Carpman and Grant, 2002; Chun-Heng, 2006; Cubukcu, 2004; Evans, 1980; Field, 1999; Gittler & Gluck, 1998; Moore, 1979). Among these studies, one group focused on three-dimensional "object" visualization ability (Chun-Heng, 2006; Field, 1999; Gittler & Gluck, 1998) and another group focused on three dimensional "space" visualization ability (Cubukcu, 2004; also see reviews by Evans 1980; Moore, 1979; Carpman & Grant, 2002).

The studies that focused on three-dimensional "object" visualization ability investigated people's ability to work with three-dimensional physical models. Such studies developed tests to measure respondents' ability to represent three-dimensional physical models on a paper. Paper folding, mental rotation, mental cutting, isometric drawing tests are examples of these tests (Chun-Heng, 2006; Field, 1999; Gittler & Gluck, 1998). For planning and architecture education, we believe that isometric drawing abilities makes more sense than other alternative tests such as paper folding. Thus, in this study, we used isometric drawing test to measure three-dimensional object visualization ability.

The studies that focused on three dimensional "space" visualization ability investigated people's ability to understand spatial environments. Such studies developed tests to measure respondents' spatial cognition and spatial orientation abilities.

To understand people's three dimensional "space" visualization ability, researchers asked participants to draw sketches, navigate between formerly experienced locations and estimate direction and distance to a known location (Carpman & Grant, 2002; Cubukcu, 2004; Evans 1980; Moore, 1979). Among these alternative tasks, we used sketching, direction and distance estimation tasks to measure three dimensional space visualization ability. Due to the time limitations, navigation task was not used in this study.

Methodology

The students studying in the Department of City and Regional Planning at Dokuz Eylul University, Izmir, Turkey, in the 2007-2008 academic year participated in the study. Participants' creativity and three dimensional visualization abilities were measured by three groups of tests: (1) creativity tests, (2) three-dimensional object visualization tests, and (3) three-dimensional space visualization tests. The archival data collected by student affairs office provide information on their academic achievement in pre-university education and their final grade in a basic design studio revealed their academic achievement in basic design education.

Creativity Tests

Thirty-four first grade students (13 male, 21 female) studying in the City and Regional Planning Department at Dokuz Eylul University, Izmir, Turkey, in 2007-2008 academic year participated in the study. Participants took the test at the beginning of their second week of university attendance.

In parallel to Moore (1970), participants were

asked to complete seven groups of creativity tests; (1) sketches, (2) alternate uses, (3) match problems, (4) consequences, (5) gestalt transformations, (6) hidden figures, and (7) hidden analogies tests. Sketches, alternate uses, and consequences tests were the same as the tests described in Denel (1981) and the remaining tests were designed based on the explanations given in Moore (1970).

Three sketch tests measured their ability to generate as many different sketches as possible from three basic geometric figures; a circle, a square, and a triangle (Figure 1). For each participant, "sketching creativity" was determined by the total number of sketches produced for three shapes. Participants who produce less than 10 sketches received a creativity score of 1, participants who produced between 10 to 19 sketches received a score of 2, and others received a score of 3.

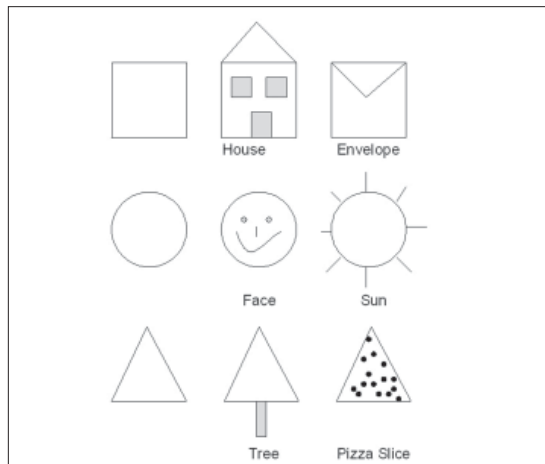


Figure 1: Participants were asked to generate as many different sketches as possible from three basic geometric figures; a circle, a square, and a triangle (Source: Authors).

Four alternate use tests measured their ability to generate as many ideas as possible to describe an alternative use for four common objects; a pencil, a gum, a table, and a rope. For each participant, "alternate use creativity" was determined by the number of ideas listed for four different objects. Participants who produce less than 5 ideas received a creativity score of 1, participants who produced between 6 to 10 ideas received a score of 2, and others received a score of 3.

A match problem test measured the participants' ability to generate alternative patterns from a complex geometrical pattern (Figure 2). An informative example would be removing matches from a pattern so that the remaining matches form a new pattern. For each participant, "match problem creativity" was determined by the number of new patterns produced. Participants who produced zero or one pattern received a creativity score of 1, participants who produced between 2 to 4 patterns received a score of 2, and others received a score of 3.

Two consequences tests measured their ability to generate as many alternative appropriate consequences as possible for two given situations. First, the participants were asked to imagine a situation where they have to produce a model for a final project, and just a night before the deadline, they realized that they are out of glue. Then, they were asked to list possible consequences for this situation. Second, the participants were asked to imagine a situation when they just saw two children broke down the mechanism that controls opening and closing of a bridge. The traffic leading to the bridge is dense and a cargo boat is sailing to the bridge.

Participants were then asked to list as many consequences as possible for this situation. For each participant, "consequence creativity" was determined by the number of ideas listed for both situations. Participants who produced less than 2 ideas received a creativity score of 1, participants who produced between 3 to 8 ideas received a score of 2, and others received a score of 3.

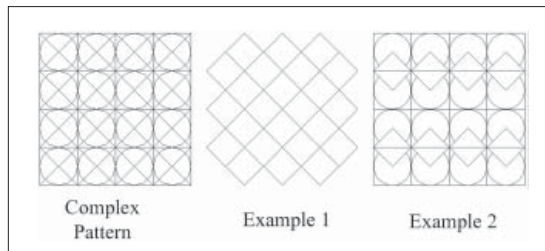


Figure 2: Participants were asked to generate alternative patterns from a complex geometrical pattern (Source: Authors).

Two gestalt transformation tests measured their ability to form a new object using parts of two other objects which consist of lines, circles, rectangles and triangles (Figure 3). For each participant, "gestalt transformation creativity" was determined by the number of new and appropriate objects. Participants who produce less than 5 objects received a creativity score of 1, participants who produce between 5 to 9 objects received a score of 2 and others received a score of 3.

Fifteen hidden figures tests measured their ability to recognize basic figures, such as circle, square, and rectangle in fifteen complex figures. Among these fifteen figures; eight were photographs and seven were art works. For each participant,

"hidden figures creativity" was determined by the appropriate responses. Participants who recognized up to 19 basic figures received a creativity score of 1, participants who recognized between 20 to 29 basic figures received a score of 2, and others received a score of 3.

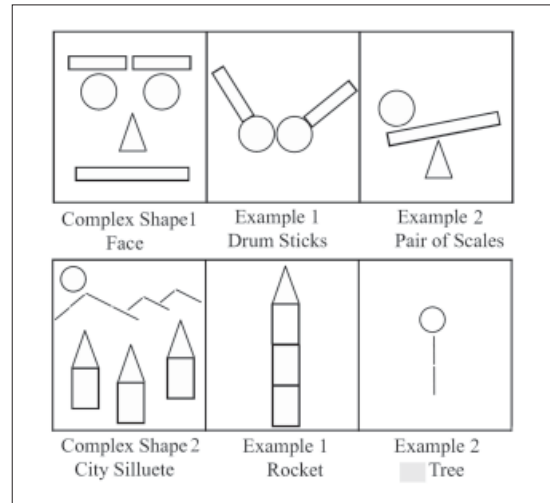


Figure 3: Participants were asked to form as many new objects as possible by using some parts (lines, circles, rectangles and triangles) of two complex shapes (abstract representation of a face or a town). (Source: Authors).

Fifteen figure analogy tests measured their ability to recognize abstract drawing of fifteen objects such as a dog, a car, a tree, and a mosque. Participants were asked to match the real objects with abstract drawing. For each participant, "figure analogy creativity" was determined by the difference between correct and incorrect responses. Participants who recognized abstract representation of up to 9 objects received a creativity score

of 1, participants who recognize abstract representation of 10 to 14 objects received a score of 2, and participants who recognize abstract representation of all 15 objects received a score of 3.

Finally, the combined creativity score was calculated by summing up all seven creativity scores. Higher scores represented higher creativity.

Three-Dimensional Object Visualization Tests

Twenty nine first grade students, twenty five of whom (11 male, 14 female) were participants of the creativity test, volunteered to participate for a course grade. Participants took the test at the beginning of their first week of second semester of university attendance. Participants were asked to complete three tasks; (1) removing cubes, (2) drawing different views, and (3) drawing isometric perspectives. All tasks required isometric drawing skills.

For the removing cubes tasks participants were given a cube formed by 64 smaller cubes (4 cubes on each of the x, y, z-axes). Then four groups of three to five cubes were removed from this 64 cube composition. For each cube group, the removed cubes were drawn next to the bigger cube, and the location where they were removed, were indicated with color differentiation on the bigger cube (Figure 4). Participants were then asked to draw four final isometric drawings showing the removed cubes in the bigger cube composition. The ability to draw isometric views for the removed cubes is measured by the sum of the correct response for each task. The correct response is

the difference between the correct lines and incorrect or missed lines. One is expected draw 10 lines for the first shape, 12 lines for the second shape, 8 lines for the third shape, and 22 lines for the last shape. Thus, the maximum score for this task was fifty-two. Participants who drew all lines correctly received an object visualization ability score of 3, participants who drew 40 to 51 lines correctly received a score of 2, and participants who drew less than 39 lines correctly received a score of 1.

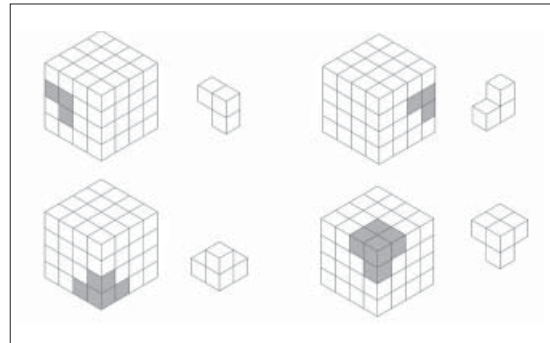


Figure 4: Participants were asked to draw four final isometric drawings showing the removed cubes in the bigger cube composition (Source: Authors).

For the drawing different views tasks, participants were required to draw top, left, and right views for four shapes (Figure 5). The ability to draw different views was measured by the sum of correct drawings. As one is expected to draw three views for four shapes, the maximum score for this task was twelve. Participants who drew 10 to 12 views correctly received an object visualization ability score of 3, participants who drew 6 to 9 views correctly received a score of 2, and participants who drew less than 5 views correctly received a score of 1.

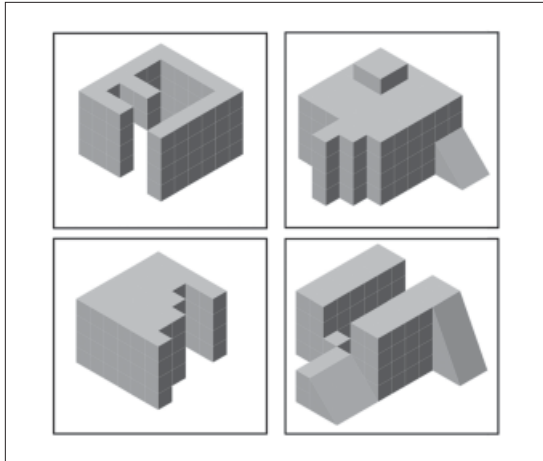


Figure 5: Participants were asked to draw top, left, and right views for four shapes (Source: Authors).

For drawing isometric perspectives tasks, participants were given two nine pixel compositions (3 rows X 3 columns), where the height of each pixel is indicated with numbers. Participants were then asked to draw an isometric perspective for each composition. The ability to draw isometric perspectives was measured by the sum of correct pixels. The maximum score for this task was eighteen (two compositions X nine pixels). Participants who drew all pixels correctly received an object visualization ability score of 3, participants who drew 10 to 17 pixels correctly received a score of 2, and participants who drew less than 9 pixels correctly received a score of 1.

Finally, a combined object visualization ability score was calculated by summing up all three object visualization ability scores. Higher scores represented higher object visualization ability.

Three-dimensional Space Visualization Tests

Participants who took the three-dimensional object visualization test took the three-dimensional space visualization test within the same day. A virtual residential environment was built using a three-dimensional modeling program, GTK Radiant. Ground-level walk-paced movement was simulated via a real-time, three-dimensional environment generator game engine, Quake III Arena. The environment comprised a rectangular area of 195 X 165 meter and contained 12 blocks consisting repeated units of three house plans. The texture maps derived from digital photographs of real buildings were overlaid onto the modeled objects to achieve detail and realism. The environment had three signs and two districts. The starting point was showed with a sign on the pavement (Figure 6).

Participants were asked to seat at a table facing a white wall. Behind them, a projector projected the simulation onto the wall at about 1 x 1 meter size. The investigator controlled the movement in the simulated environment. Thus, the participants experienced the environment for five minutes as a passenger in a car. All participants took the test together so they all have the same level of familiarity (five minutes of experience) with the environment. The participants were then asked to complete three groups of tasks: (1) a direction estimation task, (2) two distance estimation tasks, and (3) a sketching task.

For the direction estimation task, the computer automatically set the viewpoint to face the

starting point. The answer sheet showed a circle with 45-degree angles. The center of the circle represented the current location, and a point on the perimeter of the circle represented the location of the sign in the view. Participants were asked to place two marks along the circle perimeter to show the direction of the remaining two signs that are not in the view. For each sign, a direction error was calculated based on the absolute difference between the participant's estimated angle of direction and the true direction. A total direction estimation error was calculated by summing up these two scores. Participants who had less than 60 degrees of error received a space visualization ability score of 3, participants who had between 61 to 150 degrees of error received a score of 2, and the remaining participants received a score of 1.



Figure 6: A virtual residential environment was built using a three-dimensional modeling program, GTK Radiant. (Source: Authors).

There were two questions for the distance estimation task. Again, the computer automatically set the viewpoint to face the starting point. Participants were first told that the 'crow flies' distance between the starting point and the sign in the view is 10 units. The participants were then asked to estimate the crow flies distance between the starting point and the remaining two signs. Second, they were told that the 'walking' distance between the starting point and the sign in the view is 10 units and they were asked to estimate the walking distance between starting point and the remaining two signs. For each question and for each sign, a distance estimation error was calculated based on the absolute difference between the participants' estimated distance and the true distance. A total distance estimation error was calculated by summing up these four scores (two questions X two points). Participants who had 10 to 15 meters of error received a space visualization ability score of 3, participants who had between 16 to 45 meters of error received a score of 2, and the remaining participants received a score of 1.

For the sketching task, participants were shown four maps, illustrating the roads, starting point and one of the signs in the virtual environment. The maps included one correct and three distorted maps. Participants were asked to select the map that best represented the virtual environment they explored. Then they were asked to mark the location of the signs and the districts. Three scores were recorded to calculate a sketching accuracy score; (1) map selection accuracy (correct map = 1, distracter map = 0), (2) landmark location accuracy (number of correctly located landmarks, maximum score = 2), (3) district location accuracy (number of

correctly located districts, maximum score = 2). The sketching accuracy score was calculated by summing up these three scores. Participants who had no correct response received a space visualization ability score of 1, participants who had one correct response received a score of 2, and participants who had more than one correct response received a score of 3.

Finally, a combined space visualization ability score was calculated by summing up all three space visualization ability scores. Higher scores represented higher space visualization ability.

Academic Achievement in Pre-University Education

Participants' success in pre-university education was measured by their Central University Entrance Examination (CUEE) scores. As students had to pass an English exam or took a prep class for one year (or two years) before studying in the City and Regional Planning Department, CUEE scores for 2005, 2006, and 2007 were collected. Each student's rank in admission was determined by sorting the CUEE scores for each year from the lowest to the highest. Then for each student an admission percentile was calculated by dividing the student's rank in admission to total number of students entered to university in that year. The data was initially collected for 145 students; however, data for 24 students⁽³⁾, who participated in the creativity and visual spatial cognition tests, were used in the analyses. In 2005, 41 students enrolled to the program, 3 of whom participated in the study. In 2006, 52 students enrolled to the program, 13 of whom participated in the study. In 2007, 52 students enrolled to the program, 8 of whom participated in the study.

Academic Achievement in Basic Design Education

Participants' academic achievement in basic design education was measured by their average grades on the 62 first semester basic design studio tasks. Each task could be completed in approximately 3 to 20 hours. The tasks aimed to develop technical drawing skills and abstract thinking ability. These tasks aimed to enable students to understand and represent the concepts such as balance, order, harmony, contrast, emphasis, cluster, unity, and variety. Among these 62 tasks, participants were required to produce mostly two dimensional compositions, for only five tasks they were asked to produce compositions in three dimensions. For each student, each task was graded from 0 to 100. Then an average score, which was based on the completed tasks rather than all tasks, was calculated for each student.

Statistical Analyses and Results

To evaluate the effect of creativity, object visualization ability, and space visualization ability on academic success in pre-university and basic design education two General Linear Model (GLM) analyses were conducted. The GLM analyses took into account the effect of all factors simultaneously when testing the effect of each factor. The effect of gender was included in the model with the other three independent variables; creativity and object and space visualization abilities.

Table 1 shows General Linear Models on academic success in pre-university education. Results showed no significant effects for gender, creativity, and

object and space visualization abilities. This finding may suggest that the abilities not tested in this study, such as analytical skills, may effect academic success in pre-university education.

Table 2 shows General Linear Models on academic achievement in basic design education. Results showed a significant effect for object visualization ability but no significant effects for gender, creativity, and space visualization abilities. Success in basic design education increased with increases in object visualization abilities with an exception for very low and low object visualization conditions. Perhaps, there is a threshold where object visualization ability triggers achievement in design, and before one reaches that threshold, object visualization ability has no effect on success in basic design education.

Table 3 shows that the correlations between independent variables were not significant. This finding may suggest that these skills are independent from each other. Thus there is no reason to think that the effect of creativity and space visualization ability on academic achievement in basic design education was watered down by the effect of object visualization ability. In addition, the correlation between dependent variables (success in pre-university and basic design education) was not significant either. This may suggest that the knowledge and the skills required in pre-university education are not much useful in basic design studios.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	1008.862	1	1008.862	.868	.363
Creativity	24.175	1	24.175	.021	.887
Object Visualization Abilities	56.155	1	56.155	.048	.828
Space Visualization Abilities	62.782	1	62.782	.054	.819

Table 1: General Linear Models on Academic Success in Pre-University Education (Source: Authors).

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Space Visualization Abilities	62.782	1	62.782	.054	.819

Table 2: General Linear Models on Academic Success in Basic Design Education (Source: Authors).

		Creativity	Object Visualization Abilities	Space Visualization Abilities
Creativity	Pearson Correlation	1	.301	.257
	Sig. (2-tailed)	.	.143	.215
Object Visualization Abilities	Pearson Correlation		1	.057
	Sig. (2-tailed)		.	.787
Space Visualization Abilities	Pearson Correlation			1
	Sig. (2-tailed)			.

Table 3: Correlation between independent variables; creativity, object visualization ability and space visualization ability (Source: Authors).

Conclusion

The results partly confirm the claims in the literature. Creativity, object visualization ability, and space visualization ability do not affect success in pre-university education in general and Central University Entrance Examination (CUEE) scores in particular. This was an expected result as such skills are not the main emphasis in pre-university education in Turkey (Denel, 1981). Moreover this result is parallel to findings of an earlier study which showed that there is no relation between CUEE scores and graduation grades from a design based university education (Cubukcu & Cubukcu, 2007, 2009). These findings may suggest that current admission procedures to design based schools are inappropriate, and they may point to the necessity of finding alternative ways to select students for design-based higher education programs. However, suggesting alternative selection criteria for a design based program is beyond the scope of this study.

The present study shows a significant effect of object visualization ability (as expected) and insignificant effects of creativity and space visualization ability (unexpectedly) on basic design studio grades. The insignificant effect of space visualization ability on basic design studio grades may relate to the variety of tasks completed in the basic design studio. The curriculum in the first semester of the investigated design studio generally forces the students to think in small scales with reference to objects rather than large scales with reference to spaces. Perhaps, this teaching strategy may have led students to develop better three-dimensional visualization abilities for objects. However, their three-dimensional visualization abilities for larger spaces remained poor or not developed due to the above mentioned teaching strategy. Subsequent work may test the effect of object and space visualization abilities on academic success in design education in successive years. A useful extension of this study may also investigate how object and space

visualization ability changes through a four year period in various design based programs. Do students in architecture and planning departments are more likely to develop space visualization abilities while students in industrial design departments are more likely to develop object visualization ability?

In addition, there may be three explanations for the unexpected and insignificant effect of creativity and space visualization ability on achievement in a basic design studio. First, tests that were used to measure level of creativity and space visualization ability may be inappropriate. Different measures may produce a significant effect. Future studies may consider using other tests, such as Torrance tests for measuring creative thinking ability (Torrance, 1966, 1974, 1990, 1998; Torrance & Ball 1984) or navigation test for measuring space visualization ability (see review of studies using navigation test in Cubukcu, 2003). Second, this study measured academic achievement based on the tasks given in a basic design course at the end of the first semester for a group of students majoring in city and regional planning. Whether the results of the present study will apply to other design based programs such as architecture, graphic design, interior architecture remains to be seen. More work needs to be done to test the generalization of the results to larger and various groups of students. Third, on the contrary to general belief and anecdotal evidence, perhaps creativity and space visualization does not really effect academic achievement in a basic design course. Future studies may examine the reasons for it. Although the ultimate goal in design based education is to educate students to be creatively active and spatially sensitive perhaps the tasks given in design courses do

not serve to this end. If this is the case, then we need to find alternative teaching tools to raise creatively active and spatially sensitive prospective architects and city and regional planners.

As a concluding remark, this study focused whether students need creative skills and visual spatial abilities to be successful in basic design education and disregarded whether these skills are necessary to become better designers or whether they could be improved with design education. Future studies may test whether design practioners have better creativity and visual / spatial abilities than general public or test if such skills improve through out the successive years in design education.

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Notes

(1) The situation is not different In Turkey. Students are accepted to these programs based on their Central University Entrance Examination (CUEE) score, which is claimed to have no intension to measure students' creative potential and visual, spatial and perceptual

abilities (Cubukcu and Cubukcu, 2007, 2009).

(2) When the goal is undefined and equally correct alternative solutions are possible without a single optimal solution, the problem is defined as an ill-defined problem (Casakin and Goldschmidt, 1999; Casakin and Goldschmidt, 2000). With that explanation in mind, it is clear that design problems are characterized by an ill-defined structure. Salama (1995) argued that convergent and divergent thinking abilities are necessary in design. According to Salama (1995) divergent thinking refers to the ability to produce large number of possible answers and convergent thinking refers to the ability of selecting one right answer to a problem set. Although our above description of creativity (the ability to produce as many novel and appropriate alternative solutions as possible for a problem) may lead one to think that creativity relates to divergent thinking ability more than the convergent thinking ability, we do not intend to lead such a misconception. As Salama (1995) suggested, we believe a balance of convergent and divergent thinking abilities produces creative thinking ability. Yet, the available measures of creativity mostly focused on divergent thinking ability. Thus, with regard to creativity this study focused on divergent thinking ability, however future studies should investigate the convergent thinking ability in relation to creativity.

(3) One student who participated in the study was an international student thus he had no CUEE score.

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