British Journal of Education, Society & Behavioural Science
12(4): 1-13, 2016, Article no.BJESBS.22153
ISSN: 2278-0998

SCIENCEDOMAIN *international*
www.sciencedomain.org

Influence of Design Thinking Performance on Children's Creative Problem-solving Skills: An Estimation through Regression Analysis

Göksu Gözen[1*]

[1]*Department of Educational Sciences, Mimar Sinan Fine Arts University, Istanbul, Turkey.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/BJESBS/2016/22153
Editor(s):
(1) David A. Kinnunen, Department of Kinesiology, California State University Fresno, USA.
Reviewers:
(1) Milton Rosa, Universidade Federal de Ouro Preto, Brazil.
(2) José Carlos Miguel, Sao Paulo State University, Brazil.
Complete Peer review History: http://sciencedomain.org/review-history/11878

Original Research Article

Received 20th September 2015
Accepted 14th October 2015
Published 17th October 2015

ABSTRACT

This study examined the interaction of design thinking performance and creative problem-solving skills, with 89 pre-school and primary school children who attended the Architectural Design Education Program in Ankara, Turkey in the academic year 2011-2012. After each teaching session in the program, the children were assigned a performance task, which required them to solve problems involving real-life situations by creating two-dimensional (2D) and three-dimensional (3D) products. Each child kept their task-specific products in a "creative solutions portfolio". Each product in the portfolio was scored according to analytical rubrics, as a result of which indicators of both sub-dimensions (2D and 3D) and composite skills were obtained related to the children's creative problem-solving skills. Furthermore, a holistic rubric was used to assess the children's product and process performances throughout the teaching process with regard to three development areas of design thinking, i.e. basic design properties and competency, creative and visual approach in design, interdisciplinarity and cross-questioning in design. The design thinking performance was hypothesized to predict the three indicators of creative problem-solving skills of children. The findings of the regression analysis indicate that the data are consistent with the model proposed, and the results provide tentative support to the notion that design thinking performance might influence the creative problem-solving skills of children as expected. It is concluded, based on the

**Corresponding author: E-mail: goksu.gozen@msgsu.edu.tr;*

results, that educational activities for competency/development in design thinking performance may allow children to produce creative solutions for real-life problems, and hence activities that teach how to express solutions in 2D and 3D forms may be incorporated into education programs that aim to develop creative problem-solving skills.

Keywords: Creative thinking; problem-solving; design thinking; child education; performance assessment; portfolio assessment; regression analysis.

1. INTRODUCTION

Based on new socioeconomic demands and learning theories, especially those of Bruner, Dewey, Piaget, and Vygotsky, fostering students' higher-order thinking skills is regarded today not only as a key education target by a great deal of education systems around the world, but also as a highly valued phenomenon in many other domains. As stated by Wood et al. [1] and Darling-Hammond & Adamson [2], these are the so-called "21st century skills" that are increasingly in demand in a fast-changing world and are the non-routine interactive skills that allow for collaborative invention through creative thinking and problem-solving in particular.

Although the concept of creativity does not have an universally accepted definition, several studies [3-7] examining the cognitive capacities that lie under this concept argued that the basis for creativity is held to lie in the generation of high-quality, original, and elegant ideas or solutions to complex, novel, and ill-defined problems through inventing, designing, contriving, composing, and planning. This link between creativity and solving problems, termed "creative problem-solving skill", depends on the effective execution of a set of complex cognitive processes correlated to reasoning and self-directed learning, which implies an attempt to advance toward an outcome that is new, unstructured, and open-ended [8-16]. Casakin [17] suggested that since creative thinking embraces cognitive processes related to innovative problem-solving, a solution can be any type of outcome, such as an algorithm in response to a mathematical problem, an outstanding piece of art, a breakthrough in science, or a design product. Thus, not only the products of design are indicators of creative problem-solving but also design itself is a thinking skill which is defined as proactive creative problem-solving [18]. As a matter of fact, design problems cannot be solved through the application of algorithms or operators.

Salmon [19] stated that effective teachers are powerful mediators to engage children in thinking routines throughout the curriculum to provoke thinking and promote metacognitive activities. Design thinking is defined as a kind of skill framed by metacognitive phases of production and investigation, engaging a person in opportunities to perceive, visualize ideas from imagination, experiment, create and prototype two-dimensional (2D) and/or three-dimensional (3D) models, gather feedback, and redesign [20, 21,22-24]. Furthermore, the wide scope of design is thought to give teachers flexibility in helping students develop their creative thinking, critical thinking and problem-solving skills. By the survey of Programme for International Student Assessment (PISA) produced by the Organisation for Economic Co-operation and Development (OECD) [25], proficiency in creative problem-solving is found to contribute to learning how to turn real-life problems into learning opportunities – creatively devising solutions and purposely reasoning outside of school contexts. Thus, as pointed out by Kangas, Seitamaa-Hakkarainen & Hakkarainen [26], design is a way to make this possible and an effective tool which contributes potentially to a rich environment for successful learning by enhancing children's creative problem-solving skills through real-life problems and innovative mindsets. What makes design so specially suited to the concept of creative problem-solving especially in children is its open-endedness. According to Lewis [27], this ill-structured character of design requires that students resort to divergent thought processes and keep away from the formulaic.

Thus, a convincing literature on creative problem-solving has continued to grow across almost every discipline area in the last twenty years, based on the idea that a creative approach to problem-solving is a crucial cognitive process which is critical for children's capacity to make a strong contribution to innovation in their future life. However, educational initiatives tracking creative problem-solving skills through design thinking and scholastic endeavor [20,24, 26,28,29] trying to foster creative problem-solving skills through design activities (e.g. applied arts, architecture, engineering etc.) within groups of students in early primary, elementary, and secondary years of schooling have been observed to become widespread very recently. There are limited educational initiatives on the relationship between these two concepts although it is estimated logically, based on observations and discussions, that there is a strong connection between the two. One of the reasons for this is the insufficiency of estimations and indicators predicated on empirical research, indicating that design and the act of design thinking are both a dimension of creative problem-solving skills and the most effective tool for the development of this skill. Based on this consideration, the present study sets out to investigate, by regression analysis, whether design thinking performance of pre-school and primary-school children is a significant predictor of creative problem-solving skills.

2. METHODOLOGY

2.1 Participants

The research data were collected from a total of 89 pre-school and primary-school children. In the academic year 2011-2012, the children attended the Architectural Design Education Program (ADEP), adapted from the American culture in to the Turkish culture by Acer, Gozen, Alper, Baysal and Yılmaz within the project no. 110K279 funded by the Scientific and Technological Research Council of Turkey (TUBITAK). For the purpose of this study, a school was selected through random sampling among the state schools representing the middle socioeconomic level in the provincial center of Ankara. In this school, the ADEP was implemented in sections (selected from amongst a total of 30 sections), representing each stage of pre-school and primary education. The distribution of children by age and gender is provided in Table 1.

2.2 Data Collection

<u>2.1.1 Construction of portfolios, rubrics and scoring procedures</u>

A portfolio used for the assessment of students' knowledge, skills and competence in a specific field was defined by Barrett [30] as a whole involving students' original products or a collection involving students' works. Garthwait & Verrill [31] and Hewett [32] indicated that this collection is not only a product of this process, but an important component that involves both the product and the process. For the purpose of this study, the creative solutions portfolios of original products designed by children during the process they attended the ADEP were taken as an indicator of their creative problem-solving skills. The total score of portfolio was defined operationally as a level of children's creative problem-solving skills.

Table 1. Distribution of children by age and gender

Age	Female		Male		Total	
	f	%	f	%	f	%
6	3	6.8	3	6.7	6	6.7
7	4	9.1	5	11.1	9	10.1
8	4	9.1	4	8.9	8	9.0
9	10	22.7	11	24.4	21	23.6
10	12	27.3	12	26.7	24	27.0
11	11	25.0	10	22.2	21	23.6
Total	44	100.0	45	100.0	89	100.0

Amabile [33] and Csikszentmihalyi [34], cited by Lindsay & Wood [35] defined three main components of creative problem-solving: (1) domain relevant skills, (2) creativity-relevant processes, and (3) task motivation. Creativity, in particular, is referred to be facilitated when performance tasks are intrinsically motivating and authentic, that is when the assignment asks learners to construct their own responses rather than select from ones presented and the task replicates challenges faced in the real world. Based on this information, the portfolios in this study involved a total of 13 creative solution products, both 2D and 3D, created as a result of performance tasks carried out by children on the basis of real-life situations at the end of each teaching session of ADEP. Calculating the total score of creative solutions portfolio, the task-specific analytic rubrics designed individually for each of 13 components were used for the purpose of assessment. The performance scores obtained were standardized after they were transformed into T scores and then weighted in view of the total number of criteria in each rubric. In other words, the level of creative problem-solving skill of each child was defined in terms of the sum of weighted performance scores they obtained for 13 components in the portfolio. The description and weightings of components are presented in Table 2.

As seen in Table 2, in ADEP, six of performance tasks (i.e. components 1, 3, 6, 8, 9 and 13) target the acquisition of creative problem-solving skills through 2D solutions such as drawing, sketching, poster design and so on while seven tasks (i.e. components 2, 4, 5, 7, 10,11 and 12) resort to 3D

Table 2. The components of the creative solutions portfolio score: Content and the weightings

	Title of the component	Qualification	Number of criterion included	Weight of component (%)
1	Hands, Touches and Textures: My City with My Touches and Textures	Collage work	8	4.49
2	Types of Vision: My Dream Room	Object design & room maquette construction	18	10.11
3	From Points to Lines: My Way Home to School	Plan drawing	10	5.62
4	Line, Surface and Space with Mikado's Sticks: The City/Town I Plan	City modelling	10	5.62
5	Surfaces/Spaces in the Nature: Select from the Nature, Become the Architect	Structure maquette construction	16	8.99
6	Where is the Heart of this Photograph?: Heart of the Photograph	Drawing	5	2.81
7	Shelter: Home Sweet Home!	House/shelter maquette construction	18	10.11
8	Building Components: A Living House	Dramatization & poster design with photos	5	2.81
9	Be a Building: I am a Building!	Poster design	11	6.18
10	My History: My Ayasofya/Selimiye Mosque	Mosque maquette construction	25	14.05
11	Bridge: Bridge to the Home	Bridge modelling	15	8.43
12	My School: My Dream School	School maquette construction	23	12.92
13	City/Town as a Starting Point: City/Town Where I Live	Poster design	14	7.86
	Total Score for Portfolio			100

solutions, including maquette and model design. For the purpose of this research, 2D and 3D creative solutions were taken as two sub-dimensions of creative problem-solving skills. Refollowing the path for the calculation of weighted scoring for the total score of creative solutions portfolio, the sum of weighted standard scores of products no. 1, 3, 6, 8, 9 and 13 were considered to calculate the score of 2D creative solutions and products no. 2, 4, 5, 7, 10, 11 and 12 to calculate the score of 3D creative solutions.

For the development of criteria that were used in the rubrics for scoring children's products and that constituted the basis of weighting, the categories which were suggested by Guilford [36], Wiggins and McTighe [37] and O'Quin & Besemer [38] and commonly encountered for rating students' creative performance, products, outcomes and meta-cognitive thinking (explanation, interpretation, application, perspective, empathy, and self-knowledge) were considered. The assessment was based on some of the criteria defined in Table 3, selected according to the context, for 2D products and on all criteria defined in Table 3 for 3D products.

In a typical design process, ideas are generated to change the physical world and these ideas are adjusted in order to create a new construction. In this process of adjustment, a plenty of skills primarily creative problem-solving and including perceptual learning, gross and fine motor learning, verbal and visual communication, measuring, comparing, classifying and categorizing, investigating, experimenting, exploring, discovering, inferring, interpreting data, predicting, application, creative self-expression and cultural valuing should be employed together. By combining the skills given below, Taylor, Vlastos and Marshall (1991) developed the ADEP to enable individuals to acquire designing behaviors related with the mental processes: problem-solving, creative thinking, visual thinking, group interaction, and communication skills. In consideration of this theoretical frame, design thinking performance – another variable taken into consideration in this research – is defined with three indicators including observal cumulative and composite assessments of all products and process of investigation and production. These three subcategories, consistent with the processes proposed by Taylor, Vlastos and Marshall [39] are a) basic design properties and competency, b) creative and visual approach in design, and c) interdisciplinarity and cross-questioning in design. The "Rubric for Design Thinking Performance", developed as a holistic gradual key for the calculation of this score, is presented in Table 4.

2.1.2 Validity and reliability of the rubrics

Validity evidence was collected on the basis of experts' opinions for all rubrics developed in this study. Opinions were received from a specialist in Turkish Language and Literature and two specialists in Measurement and Assessment for a) language and expression, b) appropriateness of content with regard to program outcomes and developmental level of students, and c) appropriateness with regard to measurement and assessment techniques in rubrics. Revisions were made based on the opinions of experts in order to ensure content validity.

Table 3. Definitions of assessment criteria for creative products

Key Criteria	Definitions
Spatial Awareness	• Identifying the location and functions of objects in a place • Viewing the place from new perspectives and establishing a link between objects with different qualities
Explanation and Interpretation Through Visual Thinking and Creativity	• Sketching until design ideas come up • Elaborating on design ideas • Visualizing the development steps of an idea or a product • Developing sequential original ideas or products • Explaining the comprehension of a creative process (inspiration for a new product; discovery and research; waiting period; illumination and revision) • Seeing objects from a multi-perspective and in a detailed way • Saving eyes and mind from stereotypes • Being flexible, adapting to changes resulting from the emergence of an unexpected effect
Surveillance, Analytical and Critical Perspective	• Taking into consideration various interdisciplinary approaches when generating an idea or a product • Producing evidence for the trial period / experience • Producing evidence for the transformation of the process into product or idea
Application	• Explaining specific characteristics, limitations and space of materials • Drawing schemas, plans, levels and perspectives (where nuances and shadows occur) • Structuring two- or three-dimensionally both the process and the product • Making use of basic principles and concepts of mathematics, sciences or technology
Esthetics	• Showing evidence that they understand functional structure as opposed to esthetic structure • Developing qualified style, design, colors, rhythm and repetitions. • Adding a subtle meaning to the expression • Merging all elements in a meaningful, balanced and harmonious way
Communication	• Explaining the function of the idea or product fluently • Communicating the idea or product clearly through visual means with graphs

Table 4. Rubric for design thinking performance

Observed performance level	**Developmental areas**
Score*	**A. Basic design properties and competency**
4	It is observed that: • In all forms, objects and structures in the design, the lines, shapes, textures, colors and tones are used in a qualified, accurate and complete way (visual effect), • Main and supporting materials are placed in design rhythmically in a balanced and proportional way (theoretical effect), • A subtle meaning is assigned to the expression of all design products (detail), • The products have both an aesthetic structure, which refers to the accurate use of design elements and principles and a functional structure, which refers to rapid and effective conveyance of the message (holistic aesthetics), • All designs are comprehensible and clear, e.g. a bridge, road or building constructed by wooden blocks are of distinctive nature (clarity), • The living and nonliving things in design convey the message holistically, not in a disorganized or confusing way, e.g. the drawings related to the route between home and school create a whole with parts complementing each other on the paper (fluency), • Sufficient number of materials are used in design products (use of materials), • The objects, forms and textures designed are structured accurately and completely (product development phases).
3	Most of the products (about 10-11 products) have the properties listed above. However, although few in number, there are some designs that do not comply with basic design properties and requirements.
2	Only half of the products (about 6-7) have the properties listed above.
1	Only a few products (2 or 3) have the properties listed above.
Score	**B. Creative and visual approach in design**
4	It is observed that: • The textures produced were original and different from others, and the distinctive characteristics of living and nonliving things used in design are presented from a personal perspective (reflecting a child's own emotions and ideas), e.g. placing a ramp on the pavement for baby strollers, elder people and disabled people (originality/novelty), • The products (or objects, structures or light used in a product) are designed by use of attractive materials, forms, colors and locations (attractiveness), • Creative textures based on imagination are used rather than traditional textures in the expression of design products, e.g. designating a space for fruit trees in school garden or placing the windows of a building on the roof in a way that they face the sun (imagination), • The design is a product of developing different and multiple perspectives of and attributing different meanings to materials and objects in nature, and materials are used after being transformed (flexibility).
3	Most of the products (about 10-11 products) have the properties listed above. However, although few in number, there are some designs that do not reflect design-oriented creative and visual thinking skills.
2	Only half of the products (about 6-7) have the properties listed above.
1	Only a few products (2 or 3) have the properties listed above.
Score	**C. Interdisciplinarity and cross-questioning in design**
4	It is observed that: • The indicators of sensitivity to physical environment are seen in all design products, e.g. using, in design, elements and structures with various functions related to the needs of living/nonliving things, inspired by the nature (sensitivity to

Observed performance level	Developmental areas
	physical environment), • Using similarities and contrasts of textures and materials consciously in products (questioning), • Strong and direct links with real life are established in design, based on personal experience, e.g. placing a zebra crossing close to the school, not in a blind stress (establishing links), • Related to the transformation of design processes into products, trials such as drawings or sketches or other sorts of preliminary works are presented (averment), • Basic principles and concepts related to mathematics, science and technology are used in the process of product design, e.g. using physical principles in the construction of bridges, buildings, etc. from wooden blocks in order to ensure their balance, placing beds parallel to the ground or using lightning equipment in rooms (use of interdisciplinary concepts), • Visualization is ensured in design through living/nonliving things, objects and structures, based on observations and data collection, e.g. transforming an organic object into an inorganic structure by use of points, lines and volume after collecting data about this object (observation and data collection), • Living and nonliving things are transformed into new forms and posited appropriately in the physical nature in a logical order and without getting distant from their original form, e.g. constructing a factory in the form of an object selected from the nature and locating this factory away from the town center in order to avoid the harms of waste materials (solution offers for a design problem).
3	Most of the products (about 10-11 products) have the properties listed above. However, although few in number, there are some designs that do not reflect interdisciplinary links and cross-questioning.
2	Only half of the products (about 6-7) have the properties listed above.
1	Only a few products (2 or 3) have the properties listed above.

** 4= The performance observed is at an excellent level. 3= The performance observed is at a good level. 2= The performance observed is at a medium level. 1= The performance observed is at an insufficient level*

Three children from each level of age, a total of 18 children, were selected randomly to test reliability of the rubrics. The distribution of children by gender and age is provided in Table 5.

Table 5. The distribution of the children selected for reliability analysis

Age	Gender		Total
	Female	Male	
6	2	1	3
7	2	1	3
8	1	2	3
9	2	1	3
10	2	1	3
11	3	-	3
Total	12	6	18

The aim of reliability testing was to determine whether more than one raters using the same rubric could give consistent scores at the same time and/or at different times. There are various techniques used to collect such reliability evidence. Some of these techniques provide a holistic agreement based on the total score from performance products while some others provide an agreement between raters for each item in the rubrics. Both techniques were used in this study.

Correlation was used to obtain reliability evidence from total performance scores. For this, the trainer that had put the ADEP into practice previously used the related rubrics to evaluate creative solution products and design thinking performances. Simultaneously with and independent of the first rater, the same products were evaluated by a second trainer that used the same rubrics. It was observed that the correlation between repeated ratings was a high – ranging between r_{xy}=0.92 and r_{xy}=0.99, positive and significant at the level of .01 for each rubric.

On the other hand, Cohen's kappa coefficient (κ) which is a non-parametric statistic that measures inter-rater agreement for qualitative

Table 6. Symmetric measures of agreement for the criteria included in the rubrics

	Rubric	Intervals for kappa values (κ)		Level of significance
		Minimum value	Maximum value	
Creative solutions portfolio	Component 1	0.50	0.84	.000 ≤ *P* ≤ .03
	Component 2	0.42	1.00	.000 ≤ *P* ≤ .01
	Component 3	0.42	1.00	.000 ≤ *P* ≤ .01
	Component 4	0.47	1.00	*P* = .000
	Component 5	0.70	1.00	*P* = .000
	Component 6	0.55	1.00	*P* = .000
	Component 7	0.46	1.00	.000 ≤ *P* ≤ .02
	Component 8	0.56	0.83	*P* = .000
	Component 9	0.61	1.00	*P* = .000
	Component 10	0.46	1.00	.000 ≤ *P* ≤ .02
	Component 11	0.50	1.00	*P* = .000
	Component 12	0.46	1.00	.000 ≤ *P* ≤ .02
	Component 13	0.55	1.00	*P* = .000
	Design thinking performance	0.46	1.00	.000 ≤ p ≤ .02

(categorical) items [40,41] was used to obtain criterion-based reliability estimates:

$$\kappa = \frac{\Pr_{(a)} - \Pr_{(e)}}{1 - \Pr_{(e)}}$$

where $\Pr_{(a)}$ is the relative observed agreement among raters, and $\Pr_{(e)}$ is the hypothetical probability of chance agreement. This measure is generally thought to be a more robust one than simple percent agreement calculation, since it takes into account the agreement occurring by chance [42]. The reliability analysis, conducted for each criterion in the rubrics based on *κ* coefficient, indicates that the raters' scorings were consistent with regard to all criteria in the rubrics and that all agreement values obtained were significant. The results are presented in Table 6.

Based on these findings, it was concluded that all the rubrics developed were appropriate for a reliable rating with respect to both total scores and the criteria included in the rubrics.

2.2 Data Analysis

Simple linear regression was used in this study in order to investigate the power of design thinking performance to predict children's creative problem-solving skills based on creative solutions portfolios and problem-solving skills based on 2D and 3D creative solutions products. For data analyses, SPSS 19.00 was used; and in the analyses, .01 level of significance was adopted.

3. RESULTS

At the preliminary stage, it was examined whether some common assumptions underlying regression analysis were met. In this respect, the first analysis was related to normality. Descriptive statistics are given in Table 7.

The moments of symmetrical distributions constitute a significant descriptive value for determination of normality, particularly the third moment of the standard score of X, which is the skewness ($\alpha 3$), and the fourth moment of the standard score of X, which is the kurtosis ($\alpha 4$). Provided that the values of skewness and kurtosis are within the limits of ±1.00, it is considered that the scores in the distribution do not show an excessive deviation from the normal. As seen in Table 7, the distributions were close to normal as both the total score and scores of criteria for creative problem-solving skill ($-0.42 \le \alpha 3 \le -0.08$ and $-0.31 \le \alpha 4 \le 0.24$) and design thinking performance ($\alpha 3=-0.93$ and $\alpha 4=0.14$) were within acceptable values in terms of skewness and kurtosis. Kolmogorov-Smirnov test was performed to acquire more detailed information about distributions and to check univariate and bivariate normality. The results of Kolmogorov-Smirnov test were not significant neither in univariate analysis nor in individual analyses for the combination of the predictive variable (DTP) with each predicted variable (P =.20 for 2D-CS; P =.20 for 3D-CS; .19≤ P ≤.20

for CSP). Thus, the distribution of scores did not have a significant difference than the expected normal distribution. Homogeneity analysis was also performed for the distribution. The univariate tests performed by Levene's F to see whether the error variance of the dependent variable is equal across groups yielded the results showing that the test was insignificant for all dependent variables (Levene F(5-83)=1.166, P =.33 for 2D creative solutions; Levene F(5-83)=1.114, P =.36 for 3D creative solutions; Levene F(5-83)=0.269, P =.93 for total score of creative solutions portolio).

In order to get information about linearity between observations, before the analyses, the scatter plots and regression lines (total fit lines) obtained were investigated according to the values of predictive and predicted variables, and it was found that there were no outliers that were likely to compromise linearity of the relationship. The results of regression analyses conducted with respect to dependent variables are presented below in Table 8 for 2D creative solution skills, Table 9 for 3D creative solution skills and Table 10 for creative problem-solving skills obtained from children's portfolios, regardless of the type of solution.

The regression parameters in Table 8 indicate that there is a significant and moderate correlation between children's design performances and 2D creative solutions scores (R=0.652, R2=0.425, F(1, 87)=64.411, P = .000). It is also seen that children's design thinking performances are a significant predictor of their 2D creative solutions-based creative problem-solving skills (t=8.03, P =.000) and that approximately 43% of the total variance related to children's 2D creative solutions scores is explained by their design thinking performance.

Similar to regression analysis findings presented in Table 8, Table 9 shows that there is a significant and moderate correlation between children's design performances and 3D creative solutions scores (R=0.658, R2=0.433, F(1, 87)=66.507, P = .000). The parameters indicate that the regression model is statistically significant, in other words children's design thinking performances are a significant predictor of their 3D creative solutions-based creative problem-solving skills (t=8.16, *P* =.000). Furthermore, again, approximately 43% of the total variance related to children's 3D creative solutions scores is explained by their design thinking performance.

Table 7. Descriptive statistics

	Variables	Total (N=89)					
		Minimum	**Maximum**	$\overline{X}$	S_x	**Skew (α_3)**	**Kurt (α_4)**
Creative problem-solving skills	2D Creative Solutions (2D-CS)	9.81	18.35	14.88	1.81	-0.31	-0.31
	3D Creative Solutions (3D-CS)	27.67	42.59	35.12	2.88	-0.08	0.01
	Creative Solutions Portfolio total score (CSP)	39.42	58.75	50.00	3.82	-0.42	0.24
	Design Thinking Performance (DTP)	6.00	12.00	10.63	1.46	-0.93	0.14

Table 8. Regression model summary within the prediction of the dependent variable: 2D creative solutions-based skills

Independent variables	Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlations
	B	**Std. error**	**Beta**			**Zero-order**
Constant	6.05	1.11	-	5.45	.000	-
Design thinking performance	0.83	0.10	.65	8.03	.000	.65
$R=0.652$; $R^2=0.425$; $F_{(1, 87)}=64.411$; $P = .000$						

Table 9. Regression model summary within the prediction of the dependent variable: 3D creative solutions-based skills

Independent variables	Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlations
	B	Std. error	Beta			Zero-order
Constant	20.97	1.75	-	11.99	.000	-
Design thinking performance	1.33	0.16	.66	8.16	.000	.66
R=0.658; R^2=0.433; $F_{(1, 87)}$=66.507; P = .000						

Table 10. Regression model summary within the prediction of the dependent variable: Creative solutions portfolio-based skills

Independent variables	Unstandardized coefficients		Standardized coefficients	t	Sig.	Correlations
	B	Std. error	Beta			Zero-order
Constant	27.02	1.82	-	14.81	.000	-
Design thinking performance	2.16	0.17	.81	12.71	.000	.81
R=0.806; R^2=0.650; $F_{(1, 87)}$=161.651; P = .000						

Table 10 shows that there is a significant and high correlation between children's design performances and creative solutions portfolio scores, the latter being a general indicator of their creative problem-solving skills (R=0.806, R^2=0.650, $F_{(1, 87)}$=161.651, P =.000). It may also be concluded that the regression model constructed is statistically significant and that children's design thinking performance is a significant predictor of their creative problem-solving skills, regardless of the type or structure of the problem situations presented to them (t=12.71, P =.000). Approximately 65% of the total variance in creative problem-solving skills based on children's creative solutions portfolio is explained by their design thinking performance.

4. DISCUSSION AND CONCLUSION

Many conceptual studies in the literature indicate that there is a strong link between creative problem-solving and the act of design thinking. For, there is an interconnection between both definitions and processes of these two concepts. For instance, Isaksen, Dorval, and Treffinger [11] defined Noller's symbolic formula for creativity, which suggests that creativity is a function of knowledge, imagination, and evaluation. Children are particularly considered to be naturally strong in imagination, seeing the problem or challenge from many different viewpoints, generating many, varied, and unusual ideas that have high potential to address the problem or meet the challenge in a fresh and valuable way, which are also components of design thinking. In a similar manner, the results of Kangas, Seitamaa-Hakkarainen & Hakkarainen's [26] study, which focused on understanding elementary students' multimodal ways of design thinking, indicated that the students' design thinking was collaborative, materially mediated, and embodied in nature through a problem solving process. In addition to these, there are some other examples that refer to the link between these two concepts. As a matter of fact, "designing" is a commonly repeated term in theoretical definitions related to creative problem-solving skill while the terms of creative thinking and problem solving are encountered in almost all definitions related to "design/designing/design thinking" [17,18,43-46].

At the basis of design thinking is, primarily, the act of producing creative solutions to a problem at the cognitive or physical level and concretizing the solution, transforming it into a material and expressing it in 2D or 3D forms. Regardless of its type, every design is an original product of a problem-solving process. However, the indicators of creative problem-solving skills do not always necessarily turn into an action. The indicator may be in the form of an idea, a discourse or an interpretation of an observation. Based on this, it is considered that design thinking is a component and one of the predictors of creative problem-solving skill and also a tool that is likely to contribute to the development of problem-solving skills in children. Taking this idea as a point of departure, this study has set out to present a mathematical discussion on to which extent design thinking performance explains problem-solving skills, with a regression model. Research data evidential for these discussions were gathered by using performance tools (i.e. performance tasks and portfolios) and performance scoring procedures, which not only present extensive indicators for research variables, but also reflect the nature of attainment in the real world and are well suited to judging children's learning behaviours.

Research findings indicate that, children's 2D and 3D solutions-based creative problem-solving skills and design thinking performances tend to move in tandem, which means that there is a contemporaneous correlation between these two variables, i.e. their values increase or decrease together. In addition, it is determined that children's design thinking performance has a role in approximately 43% of the total variance in their 2D and 3D creative problem-solving skills. On the other hand, when the solution-producing skills for creative problems are considered regardless of the type and structure of problems (but through the common contribution of both sub-dimensions; 2D and 3D), a larger percentage (65%) of the change and development in children's creative problem-solving skills is observed in correlation with their design thinking performances. In this way, it may be asserted that the results provide tentative support to the fact that children's design thinking performance, based on three areas of development i.e. "basic design properties and competency", "creative and visual approach in design" and "interdisciplinarity and cross-questioning in design" is a significant predictor of their creative solution-producing skills and might influence them as proposed. Thus the results of this research give support to the reasonable grounds of educational initiatives tracking creative problem-solving skills through design thinking and the scholastic endeavor [20,24,26, 28,29,39] trying to foster creative problem-solving skills through several types of design activities.

Undoubtedly, it is insufficient to simply teach children how to design things, and call it creative problem-solving. However, based on the results, it is concluded that the educational activities, the aim of which is to develop and improve design thinking performance of children, may contribute to creative solutions that children produce for real-life problems. Therefore, it is argued that activities that teach how to express solution proposals in 2D and/or 3D forms should be incorporated into education programs such as arts, mathematics, science and technology for basic education levels that aim to develop creative problem-solving skills of children. As the main challenge for 21st century education systems is not only to nurture higher-order thinking skills but also to assess them alongside other education targets, it is recommended to investigate the research hypotheses further through assessment of creative problem solving and design thinking skills, and to examine a possible causal interaction between the research variables through constructing and testing possible theoretical models with a structural modeling approach.

ACKNOWLEDGEMENT

The data presented here is part of a larger study titled "The Adaptation into Turkish Culture of the Design Education Program (Architecture and Child Instruction Program). Analysis of its Effectiveness and Extending the Use of the Program", funded by The Scientific and Technological Research Council of Turkey (TUBITAK) within the Project No.110K269.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Wood D, Hole J, Payne R, Whitehead P, Winters M, Muschamp P. Creative Partnerships. National external evaluation audit report. Newcastle: Creativity, Culture and Education; 2007.
2. Darling-Hammond L, Adamson F. Beyond basic skills: The role of performance assessment in achieving 21st century standards of learning. Stanford, CA: Stanford University, Stanford Center for Opportunity Policy in Education; 2010.
3. Besemer SP, O'Quin K. Confirming the three-factor creative product analysis matrix model in an American sample. Creativity Research Journal. 1999;12:287-296.
4. Casakin HP, Kreitler S. The nature of creativity in design: Factors for assessing individual creativity. In: Gero JS, Bonnardel N, editors. Proceedings of international workshop on studying designers. Sydney: University of Sydney, Key Centre of Design Computing and Cognition. 2005;87-100.

5. Christiaans HHCM. Creativity as a design criterion. Creativity Research Journal. 2002;14(1):41-54.
6. Mumford MD, Medeiros KE, Partlow PJ. Creative thinking: Processes, strategies, and knowledge. Journal of Creative Behavior. 2012;46(1):30-47.
7. Reiter-Palmon R. Can we really have an integrative theory of creativity?: The case of creative cognition. Creativity: Theories-Research-Applications. 2014;1(2):256-260.
8. Barrett JD, Peterson DR, Hester KS, Robledo IC, Day EA, Hougen DP, Mumford MD. Thinking about applications: Effects on mental models and creative problem-solving. Creativity Research Journal. 2013;25(2):199-212.
9. Guilford JP. Way beyond the IQ. Creative Education Foundation; 1977.
10. Hester KS, Robledo IC, Barrett JD, Peterson DR, Hougen DF, Day EA, Mumford MD. Causal analysis training to enhance creative problem-solving: Performance and effects on mental models. Creativity Research Journal. 2012; 24(2012):115-133.
11. Isaksen SG, Dorval KB, Treffinger DJ. Creative approaches to problem solving: A framework for innovation and change. 3rd ed. Thousand Oaks, CA: Sage Publishing; 2011.
12. Keen R. The development of problem solving in young children: A critical cognitive skill. Annual Review of Psychology. 2011;62:1-21.
13. Mumford MD, Gustafson SB. Creative thought: Cognition and problem solving in a dynamic system. In: Runco MA, editor. Creativity research handbook. Hampton: Cresskill, NJ. 2007;2:33-77.
14. Newell A, Shaw JC, Simon HA. The processes of creative thinking. In Gruber HE, Wertheimer M, editors. Contemporary approaches to creative thinking. New York: Atherton Press; 1962.
15. Peterson DR, Barrett JD, Hester KS, Robledo IC, Hougen DF, Day EA, Mumford MD. Teaching people to manage constraints: Effects on creative problem solving. Creativity Research Journal. 2013;25(2013):335-347.
16. Robledo IC, Hester KS, Peterson DR, Barrett JD, Day EA, Hougen DF, Mumford MD. Errors and understanding: The effects of error-management training on creative problem-solving. Creativity Research Journal. 2012;24(2012):220-234.
17. Casakin HP. Factors of metaphors in design problem-solving: Implications for design creativity. International Journal of Design. 2007;1(2):21-33.
18. Baker GE, Dugger JC. Helping students develop problem solving skills. The Technology Teacher. 1986;45(4):10-13.
19. Salmon AK. Tools to enhance young children’s thinking. Young Children. 2010;65(5):26-31.
20. Bottrill P. Research note: Children thinking and learning through design activity at age six. Early Child Development and Care. 1996;121:147-163.
21. Brown T. Design thinking. Harvard Business Review, Harvard Business School Publishing. 2008;10.
22. Johansson-Sköldberg U, Woodilla J, Cetinkaya M. Design thinking: Past, pesent and possible futures. Creativity and Innovation Management. 2013;22(2):121-146.
23. Lindberg T, Noweski C, Meinel C. Evolving discourses on design thinking: How design cognition inspires meta-disciplinary creative collaboration. Technoetic Arts: A Journal of Speculative Research. 2010; 8(1):31-37.
24. Razzouk R, Shute V. What is design thinking and why is it important? Review of Educational Research. 2012;82(3):330-348.
25. OECD. PISA 2012 Results: Creative Problem Solving: Students’ Skills in Tackling Real-Life Problems. Paris: OECD Publishing. 2014;5.
26. Kangas K, Seitamaa-Hakkarainen P, Hakkarainen K. Design thinking in elementary students' collaborative lamp designing process. Design and Technology Education. 2013;18(1):30-43.
27. Lewis T. Creativity - A framework for the design/problem solving discourse in technology education. Journal of Technology Education. 2005;17(1):35-52.
28. Anderson N. Design thinking: Employing an effective multidisciplinary pedagogical framework to foster creativity and innovation in rural and remote education. Australian and International Journal of Rural Education. 2012;22(2):43-52.
29. Gözen G. Architectural design education program for children: Adaptation into Turkish culture and analysis of its effectiveness. Eurasian Journal of Educational Research. 2015;59:35-56.

Available:http://dx.doi.org/10.14689/ejer.2015.59.3

30. Barrett HC. Create your own electronic portfolio. Learning and Leading with Technology. 2000;*27*(7):14-21.
31. Garthwait A, Verrill J. E-portfolios: Documenting student progress. Science and Children. 2003;40(8):22.
32. Hewett SM. Electronic portfolios: Improving instructional practices. TechTrends. 2004;48(5):24-28.
33. Amabile TM. Creativity in context: Update to the social psychology of creativity. Boulder, CO: Westview Press; 1996.
34. Csikszentmihalyi M. Creativity: Flow and the psychology of discovery and invention. New York: Harper/Ccjllins; 1996.
35. Lindsay N, Wood D. Facilitating creative problem solving in the entrepreneurship curriculum through authentic learning activities. In: Bozalek V, Ng'ambi D, Wood D, Herrington J, Haramand J, Amory A, editors. Activity Theory, Authentic Learning and Emerging Technologies: Towards a Transformative Higher Education Pedagogy. NY: Routledge; 2015.
36. Guilford JP. Some changes in the structure-of-intellect model. Educational and Psychological Measurement. 1988;48(1):1-4.
37. Wiggins GP, McTighe J. Understanding by design. Ascd; 2005.
38. O'Quin K, Besemer SP. Using the Creative Product Semantic Scale as a Metric for Results-Oriented Business. Creativity and Innovation Management. 2006;15(1):34-44.
39. Taylor AP, Vlastos G, Marshall A. Architecture and Children: Teachers' Guide. Seattle: Architecture and Children Institute; 1991.
40. Carletta J. Assessing agreement on classification tasks: The kappa statistic. Computational Linguistics. 1996; 22(2):249–254.
41. Reynolds CR, Livingston RB, Willson VL, Willson V. Measurement and Assessment in Education. USA: Pearson Education International; 2010.
42. Krippendorff K. Content Analysis. London: Sage Publications; 2004.
43. Bruton D. Learning creativity and design for innovation. International Journal of Technology & Design Education (Int J Technol Des Educ). 2011;21:321-333.
44. Čančer V. Teaching creative problem solving methods to undergraduate economics and business students. Journal of Further and Higher Education. 2014; 38(4):485-500.
45. Kröper M, Fay D, Lindberg T, Meinel C. Interrelations between motivation, creativity and emotions in design thinking processes-An empirical study based on regulatory focus theory. In Taura T, Nagai Y, editors. Design creativity 2010. London: Springer-Verlag. 2011;97-104.
46. Long C. Teach your students to fail better with design thinking. International Society for Technology in Education (ISTE) Reports. Learning & Leading with Technology. 2012;16-20.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/11878