Metaphors in Design Problem Solving: *Implications for Creativity*

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Metaphors help designers to understand unfamiliar design problems by juxtaposing them with known situations. Retrieving concepts from metaphors demands creative thinking. While the importance of this heuristic has been acknowledged in design, more research is needed to appreciate its contribution to design practice. This investigation aims to assess metaphor use by students in design problem solving, with a particular focus on design creativity. Relationships between factors of creativity and factors of metaphors were submitted for statistical analyses. Findings show that innovation is the most significant factor characterizing design creativity, followed by utility and aesthetics. On the other hand, the synthesis of design solutions is the stronger factor of the use of metaphors, and conceptual thinking the weakest. Results also demonstrate that metaphors play an important role in design creativity. Analysis of design problems was the predictor that had a unique contribution to innovation and general creativity.

Keywords - Metaphors, Creativity, Architecture, Design-Problem-Solving.

Relevance to Design Practice - Instead of re-using known design schemas and familiar solutions, the implementation of metaphors in design practice can contribute to creative thinking and thereby to more innovative products.

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Introduction

Contemporary theories have defined *metaphors* as a structuring of our cognitive system (Lakoff, 1987; Lakoff & Johnson, 1980). Metaphors affect the way we perceive the world, categorize experiences, and organize our thoughts. These devices have a fundamental role, as they not only guide reasoning but also enhance innovative thinking. They allow the designer to think unconventionally and encourage the application of novel ideas to design problems. The employment of metaphors by architects is well documented in literature through a vast number of examples. Nevertheless, not many empirical investigations have verified the contribution of metaphors to design. In a recent study, Casakin (2004) found that metaphors help to identify and capture design concepts, as well as define goals and requirements. In another research, the aid provided by metaphors to develop unconventional solutions was seen to be more fruitful in the initial stages of the design process, known as conceptual design. Metaphor use in the final stages of the design process is more complex and therefore demands more expertise (Casakin, 2006).

Apart from knowledge and expertise, design problems require creativity. Creative thinking enables one to perceive a problem from unorthodox and innovative perspectives (Casakin & Kreitler, 2005a). To enhance their creativity, designers use different kinds of principles, tools, and heuristics, such as metaphors. Despite its significance, no empirical studies have been conducted in order to study the contribution of metaphors to design creativity.

In the first part of this research, the importance of creativity in assessing design is presented. Thereafter, a short theoretical introduction about metaphors and their application to design is included. In the second part, an empirical study conducted on a first-year design studio is described. Next, results from a survey completed by students about the assessment of their designs are presented. Finally, discussion and conclusions regarding factors of creativity and factors of the use of metaphors as predictors of design creativity are offered.

Creative Thinking and Design

Creativity is a captivating and stimulating aspect of human thinking. It has been defined as the ability to restructure old ideas to produce singular inventions (Heap, 1989) and to apply original thinking (Coyne, 1997). Creative thinking is also associated with the capacity to look critically at reality, explore unconventional alternatives, and perceive situations from innovative perspectives (Csikszentmihalyi 1997). Innovation is defined by Milgram and Davidovich (2006) as something unusual or statistically infrequent, notable, valuable, and of high quality. Creative thinking embraces cognitive processes related to innovative problem-solving. The application of innovative problem-solving can lead to the generation of remarkable and helpful solutions. (Finke, Ward, &

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Smith, 1992; Milgram & Arad, 1981). 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.

Creativity is a key element in design problem-solving. A major reason is that design is a complex and ill-structured activity, where problems cannot be solved through the application of algorithms or operators (Goel, 1995). In addition to the need for qualitative knowledge and experience, the exploration of unfamiliar and unconventional design solutions requires creative skills (Cross, 1997; Hsiao & Chou, 2004; Gero, 2000b). Creativity enables the talented designer to transcend conventional knowledge domain so as to investigate new ideas and concepts which may lead to innovative solutions. Design creativity has been investigated in relation to the design process (Candy & Edmonds, 1996; Nagai & Taura, 2006), the design solution (Dorst & Cross, 2001; Suwa, Gero, & Purcell, 2000), and the personality of the designer (Hanna & Barber, 2001; Rubinstein, 2003). However, a question that has yet to be addressed is how designers, students in particular, assess design creativity. More empirical research is needed in order to gain insight into the evaluation of creativity in design problem solving.

Factors for Assessing Design Creativity

An important issue in the creativity literature centers on how creativity in individuals can be evaluated. In a revolutionary study, Guildford (1981) operationally defined creativity through four major factors, which were put into practice to assess individual creativity. These four factors are *elaboration* (amount of detail in the responses), *innovation* (statistical uncommonness of the responses), *fluency* (quantity of appropriate responses), and *flexibility* (variety of categories of appropriate responses).

Guildford's four factors are remarkably important and quite often regarded when conducting assessments on individual creativity in different domains related to problem-solving. Therefore, they are seen to have high relevance to the design field. In this research, the four factors were included together with a group of variables used by Casakin and Kreitler (2005b) for design evaluation. These involve the following: (i) *consideration of problem constraints*; (ii) *usefulness of the design product*; (iii) *aesthetics of the design product*; (iv) *practicality of the design product*; (v*) relation of the design to the physical context*; and (vi) *value of the design product*.

Metaphors as Problem-solving Aids

Metaphors facilitate the understanding of an unfamiliar situation in terms of a known situation (Ortony, 1991). By means of metaphors, it is possible to make reference to what is clearly understood in order to elucidate the unknown. Basically, metaphors constitute an uncommon juxtaposition of the familiar and the unusual. They induce the discovery of innovative associations that broaden the human capacity for interpretation (Lakoff, 1987, 1993). For that reason, metaphors are seen as valuable aids in problem-solving tasks.

The relevance of metaphors to problem-solving is pertinent to three fundamental steps (Gentner, Bowdle, Wolff, & Boronat, 2001). The first step consists of extracting a variety of unfamiliar concepts from remote domains, where possible relationships with the problem at hand are not always evident. The second step involves establishing a mapping of deep or high-level relationships between the metaphorical concept and the problem. Correspondences are identified by means of abstractions and generalizations. Relationships of secondary importance are discarded, and only structural correspondences between the metaphorical source and the problem are set up. The last step deals with transferring and applying structural correspondences associated with the metaphorical source to the problem at hand, which at the end generally leads to a novel solution.

Metaphors and Design Creativity

In design, metaphors are viewed as heuristics that help organize design thinking and tackle *ill-defined* design problems (Antoniades, 1992; Rowe, 1987). Metaphorical reasoning is an iterative process through which designers gradually increase their knowledge of a design situation. Basically, the use of metaphors aids in structuring design problems, which by definition are *non-routine* (Gero, 2000a). Thus, when solving non-routine design problems, it is difficult to predict what a solution will look like. It is in the early stages of the design process, when fuzzy metaphors aid reflection about the essence of a situation. Reflecting on a design situation was seen to have a strong effect on the perception, analysis, and framing of a problem (Schön, 1983). Not only can metaphors assist in problem reflection but also help to break away from the limitations imposed by initial problem constraints (Snodgrass & Coyne, 1992), explore unfamiliar design alternatives, and establish novel associations with the design problem (Casakin, 2006; Coyne, 1995). These are in themselves important reasons for which metaphors are believed to stimulate design creativity.

Numerous examples illustrating the relevance of metaphors in design practice can be found in the architectural domain. For example, the dictum 'form follows function' - meaning that the external appearance of a building comes as a result of the building's internal use - influenced a whole generation of architects identified with the Modern Movement (Colquhoun, 2002). An outstanding case of the use of metaphors in practice is the design of the prairie houses by the talented architect Frank Lloyd Wright, characterized by additive simple volumes interlocking with relative freedom to each other in accordance to functional needs (e.g., Birk, 1998; Levine, 1996). 'Form follows function' was put into practice by Wright in the design of a large number of works, such as the Robie House at Chicago, the Fricke

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House, the William Martin House, the Oscar Balch House, and the Unity Temple, all these at Oak Park (See Figures 1-5). Another celebrated architect that uses metaphors is Mies van der Rohe. His memorable metaphor 'less is more' makes reference to the engineering idea of reducing architectural design to its minimal and basic nature. The application of metaphor in his work was achieved by means of reducing spatial dimensions to the minimum habitable, eliminating unnecessary materials and decoration, as well as designing simple but not simplistic details (for a complete list of buildings, see Carter, 1999) (See Figure 6).

The design literature is rich in examples of metaphor use in design. However, with the exception of a few studies (e.g., Casakin 2006; Coyne, 1997), metaphorical thinking was not empirically investigated in design. It is claimed that more research

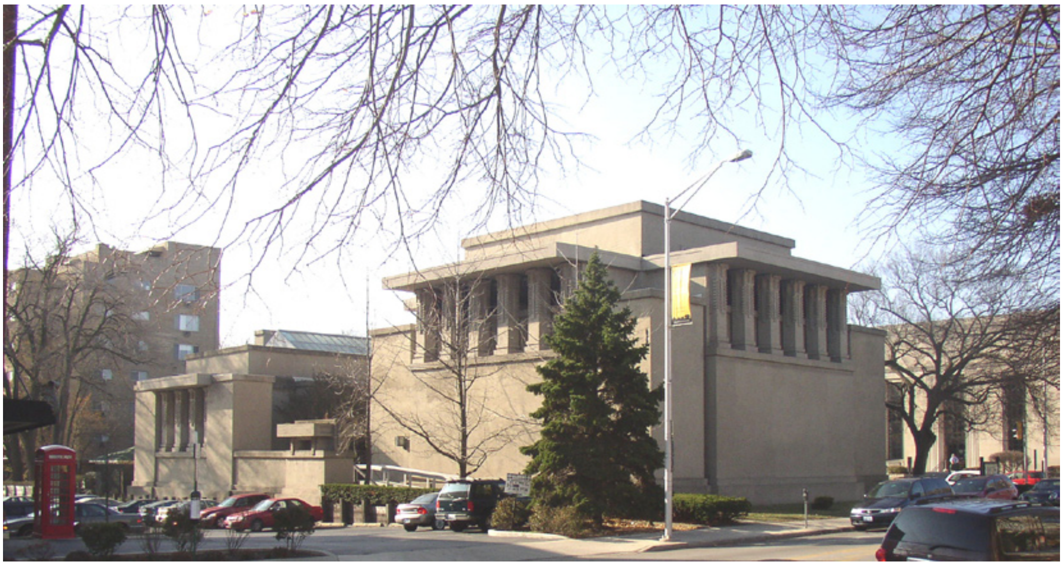

Figure 1. Unity Temple, Oak Park, Illinois, 1904-1907, by F. L. Wright. External form reflects the idea of a fortress protecting the sanctuary from external noise. Photographer: Damian Trostinetzky.

Figure 2. Frederick C. Robie House, Chicago, Illinois, 1906-1909, by F. L. Wright. External form as an outcome of internal use. Photographer: Damian Trostinetzky.

Figure 3. William G. Fricke House (also known as Emma Martin House), Oak Park, Illinois, 1901-2, by F. L. Wright. External form generated as a single composition by the addition of a variety of volumes. Photographer: Damian Trostinetzky.

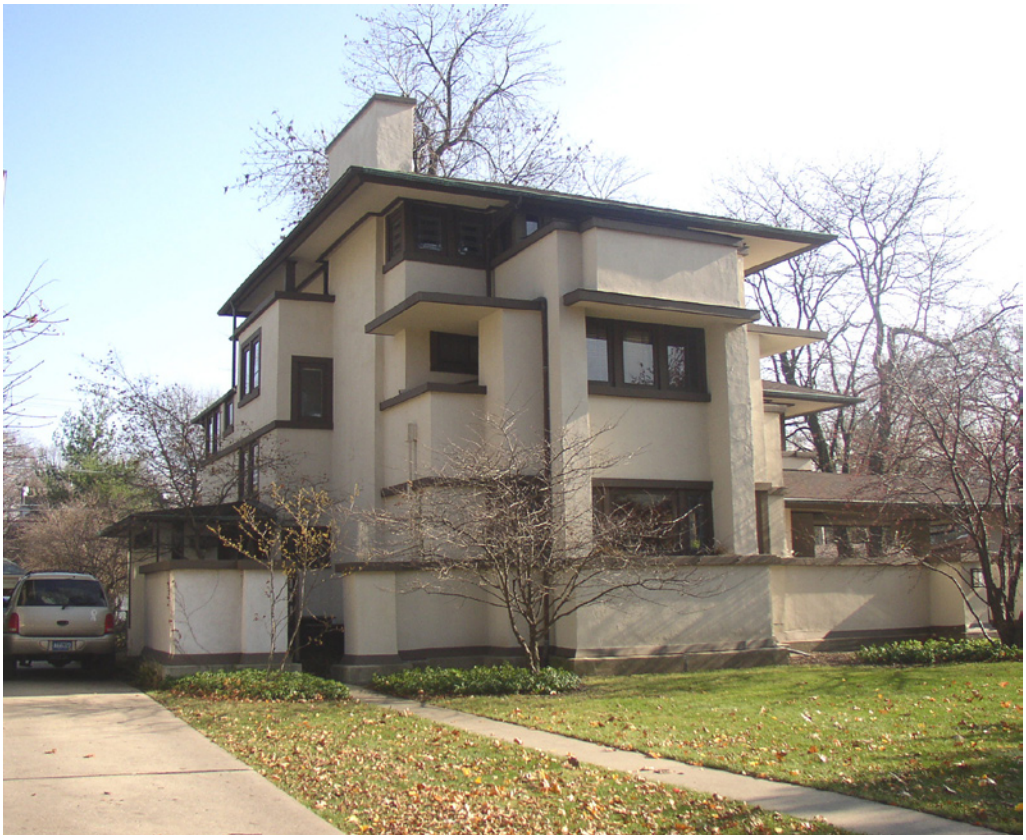

Figure 4. William Martin House, Oak Park, Illinois, 1909, by F. L. Wright. Vertical interlocking of rectangular masses containing different functions makes a striking composition. Photographer: Damian Trostinetzky**.**

Figure 5. Oscar Balch House, Oak Park, Illinois, 1911, by F. L. Wright. A three part arrangement for the living spaces is reflected in the external organization. Photographer: Damian Trostinetzky.

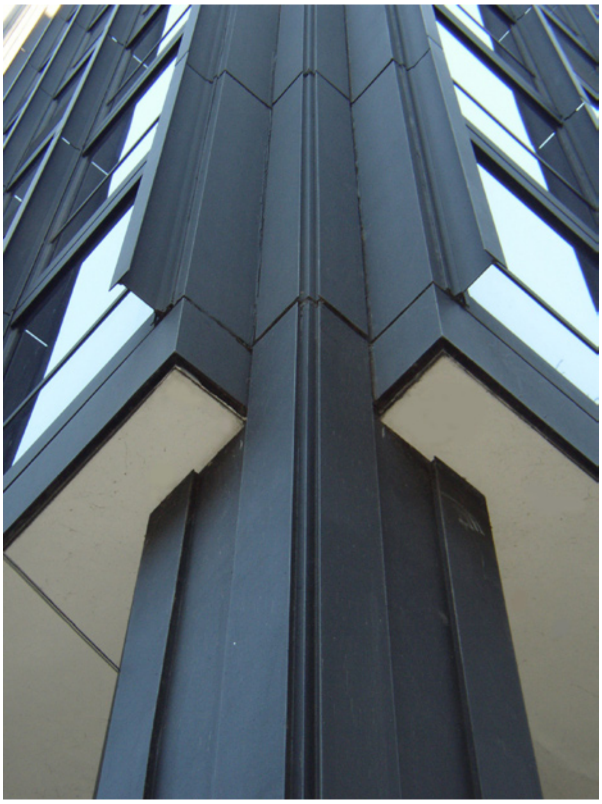

Figure 6. Lake Shore Drive Apartments, Chicago, Illinois, 1948-51, by Mies van der Rohe. View of the corner façade based on simple but not simplistic details. Photographer: Damian Trostinetzky.

is needed to study the contribution of this cognitive strategy to design problem-solving and design practice in general and to design creativity and design education in particular.

Research Goals

In the first years of design education, the development of the design process is complex and not always understood. The application of knowledge transmitted by design teachers to solve a design problem demands some level of expertise and skills that novice students do not always have. Sometimes, a hidden curriculum of architectural design education is used to control the quality of designs and to impose a status quo architectural theory (Ward, 1990). This authoritarian educational system results in a negative impact on novice students in particular, who are weak problem solvers and learn skills of how to cope with the imposed rules, instead of gaining knowledge for becoming creative architects. Therefore, as an alternative to these educational design approaches, the current research focuses on metaphor use in creative problem solving in the context of first-year design studio. These tools are considered as a major aid for helping novice students foster their own concepts and ideas in developing design solutions and for overcoming their lack of knowledge and experience.

The first goal of this investigation was to examine how students of architecture assess the creativity of their own design processes and outcomes and to gain insight in how they behave with the use of metaphors as a new tool for design problem solving. The second goal was to determine the contribution of the different factors of metaphors and creativity to design problem solving. In particular, we wanted to know whether there were significant differences in the variance of each factor. The third goal was to identify significant correlations between these factors. The fourth goal was to determine what factors of metaphor best serve as predictors of design creativity by applying regression analyses on each.

Methods

Participants

Sixty-five students (28 men and 37 women) in their first year of architectural studies took part in this research. The age range was from 21 to 41 (M=25.29, SD=3.66) with most born in Israel (81.3 %). All of them were unpaid volunteers, who received no additional course credits for their participation.

Design Task

Once a prosperous area of Tel Aviv characterized by an active food market but nowadays a deteriorated neighborhood of the city, the Old Bus Station was the district selected as the design project assigned to the students. The students were asked to design a mixed-use compound consisting of fifteen dwellings and a series of small-size public buildings. The aim of the design was to improve the environmental quality and image of the neighborhood. Students were requested to produce a brief that states the design goals, design requirements, and programmatic needs.

Procedure

Eighteen sessions organized into two meetings per week, four and a half hours per session, were devoted to the design of the mixed-use compound. The first task lasted three meetings and consisted on the analysis of 'how people live and use the city.' Students were requested to make a personal interpretation about the concept of 'urban life,' and create an abstract 3D mockup representing their ideas. In the following two design sessions, students visited the Tel Aviv Bus Station area and analyzed the structure of the neighborhood focusing primarily on the morphological, sociological, and functional features. In particular, they were asked to study interactions between everyday activities carried out by residents and the physical environment. Students also looked for alternative environments suitable for their design aims. Aided with the use of metaphors, in the next three sessions, students were requested to explore the design problem. Concepts extracted from various metaphorical sources helped them to reinterpret conventional design situations anew. During the different phases of the design task, students engaged in a cyclical process, where a series of sketches, drawings, and 1:100 and 1:200 mock-ups were produced. The last ten meetings were dedicated to the development of the design concept and to arrive at a solution that would meet the initial design requirements. Four teachers assisted and guided the students along the different stages of the design process. Figure 7 shows an example of a design solution provided by Oren Brudner, a first-year design student. The project, conceived for young students living alone in small dwellings, was based on a concept extracted from the metaphor 'the city as a bazaar of knowledge.'

Questionnaire

Upon completion of the design task, a survey on the use of metaphors and design creativity was conducted. Students were

(a)
(b)
(c)

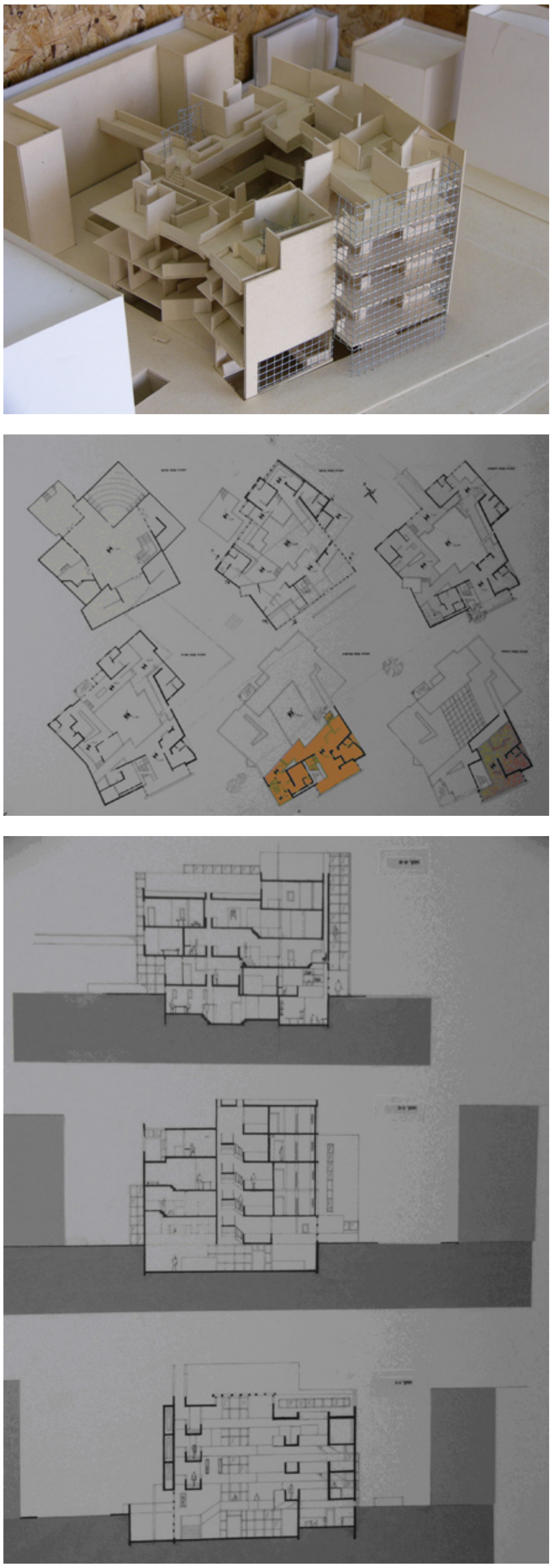

Figure 7. Example of a design solution of the fifteen dwellings by Oren Brudner, a first-year design student. (a) Mock-up of the dwelling located in the Old Bus Station area of Tel Aviv. (b) Plan drawings. (c) Section drawings.

requested to assess the creativity of their projects and the aid of metaphors in the design process. The questionnaire included eleven questions dealing with design creativity and fourteen questions regarding the use of metaphors (See Tables 1 and 2). Each question included an explanation of the aspect under assessment and a rating from 1 (minimum) to 5 (maximum).

Table 1. Listing of items in the survey on attitudes about design creativity

Items	Mean	*SD*
Fluency of the design process	2.50	0.61
Functionality of the design product	2.71	0.67
Innovation of the design product	2.75	0.77
Consideration of initial problem constraints	2.01	0.78
Aesthetics of the design product	3.03	0.76
Elaboration of the design product	3.12	0.60
Practicality of the design product	3.38	0.70
Relation of the design to the physical context	2.88	0.80
Value of the design product	3.06	0.67
Flexibility in the design process	3.19	0.54
Productivity in the design process	3.07	0.88

Table 2. Listing of items in the survey on attitudes about the role that metaphors play in design

Items	Mean	*SD*
Organize design thinking	2.93	0.83
Think more conceptually than concretely	2.81	0.85
Ask critical questions to frame the design situation	3.06	0.79
Engage in an efficient design process	2.59	0.77
Search relationships between remote domains and the design problem	2.77	0.71
Gain a deep insight into the design problem	2.90	0.73
Produce a novel design	2.78	0.76
Analyze the problem from a different viewpoint	3.01	0.75
Approach the problem by looking at general rather than small details	2.78	0.79
Arrive at unexpected outcomes	2.91	0.74
Define design objectives	2.99	0.70
Generate design alternatives	2.87	0.75
Look for singular ideas	2.76	0.78
Develop an in-depth central design idea	3.03	0.75

Results

In the first part of this section, we examined how students of architecture evaluate their own designs according to factors of creativity and metaphors. In the second part, we evaluated correlations between and within these factors. Finally, we carried out regression analyses by considering factors of metaphor as predictors of design creativity. Responses obtained from the survey were submitted to Factor Analysis, Cronbach's Alpha, Pearson Product Moment Correlation, and Multiple- Regression statistical tests.

Factor Analysis and Reliability of Creativity

The analysis of creativity assessment by design students was carried out in a sequence of three steps. In the first step, the degree of correspondence between each creativity variable included in the questionnaire was checked. This was done in terms of a reliability procedure (Cronbach's Alpha = .646). The second step consisted of applying factor analysis to the 11 different creativity variables (See Table 3). Three valid factors resulted from this operation, as is indicated by their values (>1.00) and the percents of the variance for which they account (>53.07%). The first factor accounts for 26.21% of the variance and has high saturation on the variables of 'value,' 'elaboration,' 'innovation,' 'relation to context,' and 'consideration of initial problem constraints.' Since 'elaboration, value, and innovation' are all related to the creation of an original and valuable product, and 'relation of the design to its context is an important part of problem constraints,' the first factor was named *'Innovation and constraints in design.'* The second factor accounts for 15.30% of the variance and has high saturation on the variables of 'functionality,' 'productivity,' 'flexibility,' and 'practicality.' Therefore, the second factor was named '*Utility and adaptability in design.*' Of all the factors, the third is the weakest one, because it accounts for only 11.55% of the variance. It has high saturation on 'fluency' and 'aesthetics,' and therefore labeled '*Fluency and beauty.*'

In the third step, the degree of correspondence between the variables of each creativity factor was assessed. This was done in terms of a reliability procedure. It was found that the reliability coefficient for the first factor labeled 'Innovation and constraints in design' resulted in Cronbach's Alpha = .685; the reliability coefficient for the second factor 'Utility and adaptability in design' was Cronbach's Alpha = .525; and the reliability coefficient for the third factor 'Fluency and beauty' was Cronbach's Alpha = .470. Descriptive statistics of the major factors of creativity can be seen in Table 3, and the coefficients of the questions in each factor can be seen in Table 4.

Factor Analysis and Reliability of Metaphor

A factor analysis on the metaphors considered by students was carried out in a sequence of three steps. The first step consisted of checking the degree of correspondence between each metaphor variable included in the survey. This was done in terms of a reliability procedure. It was possible to see that the reliability coefficients were high (Cronbach's Alpha = .923). In the second step, factor analysis was applied to the 14 different variables related to the use of metaphors (See Table 5). Three valid factors were found in this procedure, as is shown by their values (>1.00) and the percent of variance for which they account (>68.91%). The first factor is the most dominant one and accounts for 52.79% of the variance. It has high saturation on the variables of 'engage in an efficient design process,' 'produce a novel design,' 'generate design alternatives,' 'define design objectives,' 'arrive at unexpected

Table 3. Descriptive statistics of creativity and their corresponding factors (N=65)

Factors	Minimum	Maximum	Mean	*SD*
General Creativity Factor	2.36	3.88	2.90	.33
Factor 1: Innovation	1.60	4.00	2.76	.49
Factor 2: Utility and Adaptability	1.75	4.00	3.18	.48
Factor 3: Fluency and Beauty	1.55	3.89	2.76	.56

Table 4. Factor analysis of students' evaluations of creativity in their design work

Groupings of themes	Factor 1	Factor 2	Factor 3
Value	**.815**	.264	.086
Elaboration	**.683**	.300	.016
Innovation	**.609**	-. 446	.109
Relation to context	**.605**	-. 033	-. 039
Problem constraints	**.527**	.068	.498
Functionality	.055	**.706**	.097
Productivity	-. 151	**.584**	.148
Flexibility	.231	**.564**	-. 037
Practicality	.385	**.562**	-. 020
Fluency	-. 034	-. 086	**.869**
Aesthetics	.064	.421	**.619**
Eigenvalue	2.883	1.683	1.271
Percent of variance	26.210	15.303	11.557

Note: The numbers in the cells are saturation of the variables on each of the factors. The highest saturation level considered for defining the factor is shown in bold type.

Factor analysis was performed according to the principal components rotated varimax procedure after Kaiser normalization.

Table 5. Factor analysis of students' evaluations of metaphors in their designs

Groupings of themes	Factor 1	Factor 2	Factor 3
Engage in an efficient design process	**.811**	.203	.017
Produce a novel design	**.810**	.383	.078
Generate design alternatives	**.799**	.295	.126
Define design objectives	**.703**	.392	-. 044
Arrive at unexpected outcomes	**.655**	.264	.163
Develop an in-depth central design idea	.631	.403	.084
Ask critical questions to frame a design situation	.223	**.806**	.034
Organize design thinking	.331	**.800**	.135
Search relationships between remote domains and problem	.256	**.749**	.251
Gain a deep insight into the design problem	.359	**.733**	.001
Look for singular solutions	.414	**.668**	.039
Analyze the problem from a different viewpoint	.512	**.606**	.236
Think more conceptually than concretely	-. 034	.045	**.926**
Approach problem by looking at general rather than in small details	.472	.300	**.595**
Eigenvalue	7.391	1.205	1.052
Percent of variance	52.790	8.608	7.518

Note: The numbers in the cells are saturation of the variables on each of the factors. The highest saturation level considered for defining the factor is shown in bold type.

Factor analysis was performed according to the principal components rotated varimax procedure after Kaiser normalization.

Table 6. Descriptive statistics of metaphor and their corresponding factors

Factors	Minimum	Maximum	Mean	*SD*
General Metaphor Factor	1.14	3.93	2.87	.54
Factor 1: Synthesis of Design Solutions	1.33	4.00	2.86	.61
Factor 2: Analysis of Design Problems	1.00	4.00	2.90	.63
Factor 3: Conceptual Thinking	1.00	4.00	2.80	.68

Table 7. Correlations between the factors of creativity (N=65)

Factors		'General creativity'	'Innovation and constraints in design'	'Utility and adaptability in design'	'Fluency and beauty'
'General creativity'	Pearson Correlation Sig. (2-tailed)	1	.770 ***	.715 ***	.495 ***
'Innovation and constraints'	Pearson Correlation Sig. (2-tailed)		1	.212 ns	.173 ns
'Utility and adaptability'	Pearson Correlation Sig. (2-tailed)			1	.252 **
'Fluency and beauty'	Pearson Correlation Sig. (2-tailed)				1

* p <.05, ** p < .01, *** p < .001, ns p >.05

outcomes,' 'develop an in-depth central design idea .' Since most variables can be associated with the practical or productive role of metaphors to solve design problems, the first factor was named contribution of metaphors to the '*Synthesis of design solutions*.' The second factor accounts for 8.60% of the variance. It has high saturation on the variables of 'ask critical questions to frame the design situation,' 'organize design thinking,' 'search relationships between remote domains and the design problem,' 'gain in-depth insight into the design problem,' 'look for singular ideas,' 'analyze the problem from a different viewpoint.' Since most variables deal with the inquisitive and analytic role of metaphors in design problems, the second factor was labeled contribution of metaphors to the '*Analysis of design problems*.' The third factor is the weakest one and only accounts for 7.51% of the variance. It has high saturation on the variables of 'think more conceptually than concretely' and 'approach the problem by looking at general rather than in small details.' Since both aspects have to do with the use of abstraction and generalization, the third factor was termed contribution of metaphors to *'Conceptual thinking*.*'*

In the third step, the degree of correspondence between the variables of each factor of metaphor was assessed through a reliability procedure. It was observed that reliability coefficient for the first factor 'Synthesis of design solutions' was Cronbach's Alpha = .896; the reliability coefficient for the second factor 'Analysis of design problems' was Cronbach's Alpha = .900; and the reliability coefficient for the third factor 'Conceptual thinking' was Cronbach's Alpha = .536. Coefficients of questions in each major factor of creativity can be seen in Table 5 and their descriptive in Table 6.

Correlations Between the Factors of Creativity

Correlations within the creativity factors were analyzed through a Pearson product moment. Strong relations with significant correlations were found between most factors. Significant correlations were observed between the 'General creativity' factor and the three other factors, as well as between 'Utility and adaptability' and 'Fluency and beauty' factors. However, no significant correlations were obtained between 'Innovation and constraints in design' and the other factors (See Table 7). The data corresponding to the variable 'General creativity' was obtained by computing the mean of the 11 items presented to students in the Survey of Attitudes about Design Creativity.

Correlations Between the Factors of Metaphor

Correlations within the factors of metaphor were analyzed through a Pearson product moment. Strong relations with significant correlations were found between all factors as indicated in Table 8. 'Analysis of design problems' was the stronger correlated factor. The data for the variable of 'General use of metaphors' was obtained by computing the mean of the 14 items presented to students in the Survey of Attitudes about the role played by the use of Metaphors in Design.

Pearson Product-moment Correlations Between the Factors of Creativity and Metaphor

Correlations between factors of metaphor and creativity were analyzed through a Pearson product moment (See Table 9). It should be noted that each of the metaphor factors was related to one or more creativity factors. The following are some remarkable findings:

Table 8. Correlations between the factors of metaphor (N = 65)

		'General use of metaphors'	'Synthesis of design solutions'	'Analysis, of design problems'	'Conceptual thinking'
'General use of metaphors'	Pearson Correlation Sig. (2- tailed)	1	.918 ***	.927 ***	568 ***
'Synthesis of design solutions'	Pearson Correlation Sig. (2- tailed)		1	.748 ***	.385 ***
'Analysis, of design problems'	Pearson Correlation Sig. (2- tailed)			1	.415 ***
'Conceptual thinking'	Pearson Correlation Sig. (2- tailed)				1

* *p* <.05, ** *p* < .01, *** *p* < .001

Table 9. Correlations between the factors of metaphor and creativity (N=65)

			Metaphor assessing factors			
			'General use of metaphor'	*'Synthesis of design solutions'*	*'Analysis, of design problems'*	*'Conceptual thinking'*
Creativity assessment factors	'General creativity'	Pearson Correlation Sig. (2- tailed)	.449 ***	.411 ***	.488 ***	.057*
	'Innovation and constraints in design'	Pearson Correlation Sig. (2- tailed)	.462 ***	.394 ***	.482 ***	.192 ns
	'Utility and adaptability in design'	Pearson Correlation Sig. (2- tailed)	.208 ns	.208 ns	.242 *	-.065 ns
	'Fluency and beauty'	Pearson Correlation Sig. (2- tailed)	.200 ns	.202 ns	.248 *	-.110 ns

* *p* <.05, ** *p* < .01, *** *p* < .001

1. 'General creativity' was related significantly to all the metaphor factors.
2. 'Innovation and constraints consideration' was the most significantly related creativity variable, followed by 'Utility and adaptability'.
3. 'Fluency and beauty' was the least correlated variable.
4. 'Analysis of design problems' was the most correlated factor of metaphors.
5. While the assistance of metaphors in the 'Synthesis of design solutions' was correlated with 'Innovation and constraints consideration' 'Conceptual thinking' was the weakest factor, correlated only with 'General creativity.'

Regression Analysis Between Factors of Metaphors and Creativity

In this study, the independent variables are those that assess the metaphor use, while the dependent variables are those that assess the factors of creativity. Regression analysis was carried out to test the contribution of metaphor use to design creativity. The regression equation that predicts 'General factor of creativity' was significant. As can be seen from Table 10, factor 2 of metaphors dealing with 'Analysis of design problems' has a positive significant impact on the 'General factor of creativity' (beta=.465**) and on factor 1 of creativity, referring to 'Innovation and constraints considerations in design' (beta=.431*). On the other hand, factor 3 of metaphors, dealing with 'Conceptual thinking' was found to have a negative but significant effect on 'Fluency and aesthetic aspects' of design (beta=-.264*). An additional regression analysis was performed to test the contribution of metaphor use to the independent variable dealing with 'Overall creativity in design product.' Results confirmed the positive significant impact of the factor 2 of metaphors dealing with 'Analysis of design problems' on 'Overall creativity in design product' (beta=.437*) (See Table 11).

Discussion

A factor analysis of the 11 variables that deal with design creativity resulted in three valid factors. The first and most important factor had an emphasis on 'Innovation and constraints considerations' in design. The second factor had an emphasis on 'Utility and adaptability' in design. The third factor is the weakest and had

Table 10. Results of significant regression analysis with the metaphor factors as predictors and creativity assessment variables as dependent variables

		Creativity Factors			
		General factor	***Factor 1***	***Factor 2***	***Factor 3***
Metaphor Factors	Factor 1	.135	.078	.097	.081
	Factor 2	.465**	.431*	.256	.297
	Factor 3	-.188	-.017	-. 209	-. 264*
	F[a]	7.596	6.258	2.152	2.750
	R^2	.272***	.235***	.096	.119*

* *p* <.05, ** *p* < .01, *** *p* < .001

Table 11. Results of significant regression analysis with metaphor factors as predictors and 'overall creativity in design product' as dependent variable

Metaphor factors	Overall creativity in design product
Factor 1	.024
Factor 2	.437*
Factor 3	-.115
Fa	4.377
R2	.177**

* *p* <.05, ** *p* < .01

saturation on 'Fluency and aesthetic aspects.' These findings suggest that when students are requested to evaluate design creativity, their attention is mainly directed toward the innovation of a design. Another important issue is that for a design to be creative, it must first satisfy initial design constraints.

In addition, three major factors were found in the factor analysis of the 14 variables of metaphors in design. While the first factor had a strong contribution to the 'Synthesis of design solutions,' the second factor had an impact on the 'Analysis of design problems,' and the third and weakest factor had saturation on 'Conceptual thinking.' Most literature conceives metaphors as analytical devices that facilitate the understanding of an unknown situation in terms of a familiar one (e.g., Lakoff, 1993; Ortony, 1991). It is interesting to note that the use of metaphors was seen by students mainly as a tool supporting the production of innovative design solutions. Only thereafter, students valued the analytical and conceptual role of metaphors in design. First-year design students who lack expertise and have not developed cognitive schemas (Lawson, 2004) might have found it easier to think in terms of concrete and practical situations while dealing with the design situation.

Although significant correlations were obtained between the 'General creativity' factor and the three factors of creativity, no significant correlations were observed between 'Innovation and constraints in design' and the other two factors. This last finding supports the argument that innovation is a major aspect of creativity, which is remarkable from a theoretical point of view. One of the reasons is that in the domain of creativity there is a continuing debate about the definition of creativity, with the two major components discussed being innovation and utility.

Furthermore, significant correlations were found between the 'General use of metaphors' and all three factors of metaphors. The most correlated factor was 'Analysis of design problems,' while the stronger correlation was found between this factor and the 'Synthesis of design solutions.' Analyzing a design solution and elaborating on it is an ongoing process where designers set up a reflective dialogue with their materials (Schon, 1983). The strong correlation found between analysis and synthesis shows that both factors are necessary components of this cyclical and interactive process.

From additional analyses, a correlation between the factors of metaphor and creativity was determined. The argument that metaphors support creativity was reinforced by the finding that all the factors of metaphor were correlated to at least two creativity variables, as well as to the 'General creativity' factor. While 'Analysis of design problems' was the most correlated factor of metaphors, 'Innovation and constraints' was the most significantly related factor of creativity. It can be said that the use of metaphors, in particular 'Analysis of design problems,' has a strong contribution to creativity, and especially to innovation. 'Utility and adaptability' was the second most correlated creativity factor to 'Analysis of problems.' Retrieving a design concept from a metaphor belonging to a remote domain demands from the designer to be practical and flexible for adapting the concept to the design problem at hand.

The importance of 'Analysis of design problems' was confirmed through regression analysis, where the contribution of each factor of metaphor to creativity was analyzed separately. The regression equation that predicted the role of metaphors in 'Analysis of problems' had a significant and unique contribution to the 'General factor of creativity,' and to 'Innovation and constraints in design.' Regression analysis between metaphors and the dependent variable of 'Overall creativity in the design product' reconfirmed this result. Another regression analysis showed that the predictor of 'Abstract thinking' had a significant but negative impact on 'Fluency and aesthetics.' Although metaphors are initially used to retrieve abstract concepts from remote and unconnected sources, as the design process develops, designers become more fluent in their outcomes. Fluency enables the exploration of design alternatives and increases the chance of developing detailed and aesthetic design solutions.

Conclusions

Metaphors are viewed as cognitive strategies that assist in the organization of design thinking. This investigation was concerned with the study of metaphors in design problem solving, with implications for design creativity. The assessment of the use of metaphors and creativity in an architectural design studio was analyzed through main factors. Significant differences in variances were found between each of these factors. ‘Innovation’ as opposed to ‘Utility’ or ‘Fluency’ was the most dominant factor of design creativity and related strongly to the other factors. This finding confirms the view that, independent of the domain of study, ‘Innovation’ represents the essence of creativity.

On the other hand, ‘Synthesis of design solutions’ and ‘Analysis of design problems’ were found to be the most dominant factors of metaphors. These two factors were also found to be strongly related to ‘General creativity’ and in particular to the factor of ‘Innovation.’ Therefore, it can be asserted that the most important role that metaphors play in design problem solving is to support the design of innovative products. In contrast, the use of metaphors did not help so much in the functional and aesthetic aspects of design, such as ‘Utility and adaptability’ or ‘Beauty,’ nor did it help in the development of a dynamic and fluid design process. Although students were able to enhance the originality of their products, they were not fluent enough to produce design alternatives. Surprisingly, metaphors were mainly seen by students as fundamental aids for the ‘Synthesis of solutions in design practice’ and less helpful for ‘Analysis of design problems.’ However, ‘Analysis of design problems’ was highly correlated with all the creativity factors and, as a consequence, was a major predictor of innovation and general creativity.

It is maintained that novice students lack the necessary analytical skills to reflect in-depth on design situations and therefore face some difficulties in using metaphors as a primary analytical tool. The acquisition of analytical skills and the ability to perceive a problem from different viewpoints is related to the development of expertise. It is well documented in the problem-solving literature that differences in skills between novices and experts are attributed to differences in their analysis and representation of knowledge (e.g., Chi, Feltovich, & Glasser, 1981; Lesgold, 1991; Newel & Simon, 1972). Experience in a certain domain allows the generation of abstract or conceptual problem representations and enhances the probability of analyzing a problem more in-depth, by focusing on structural features. Experts are more likely to represent problems qualitatively, and quite often apply conceptual thinking to produce abstract and symbolic representations (Medin & Ross, 1990). The low level of expertise of the students that participated in this study is a possible reason due to which ‘Conceptual thinking’ was the weakest factor of metaphors and was unrelated to all factors characterizing creativity. It can be said that more expertise is needed to use metaphors in a better way.

The use of metaphors has important implications for design practice. As expertise develops, along with stronger abilities in analysis, synthesis, and conceptual thinking, the use of metaphors can help to stimulate creativity in design activities. Instead of re-using known design schemas and familiar solutions, the implementation of metaphors in practice can contribute to unconventional thinking and thereby generate more innovative design products.

Apart from dealing with innovation in design, future intervention programs in the design studio must regard more extensive aspects, such as functional and practical design issues. Intervention programs should also encourage students to be more fluent and consider more design alternatives before engaging in the synthesis of a final design solution. These will not only improve analytical abilities but also stimulate design creativity.

The scope of the present investigation has been limited to a study on how novice architecture students assess the use of metaphors and the creativity of their own designs. In a future study, we will extend this research to explore the assessment of metaphors and design creativity by experts and compare it with assessments from novice students.

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