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Evaluating Creativity in Design Problem Solving

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Design problem solving is characterized by being ill-structured and non-routine. In contrast to well-structured problems, design problems cannot be clearly defined because initial conditions are not provided or are quite fuzzy, goals are not fully formulated or are confusing, and operators for solving problems cannot be directed by specified algorithms (Buchanan, 1992; Reitman, 1964; Rittel and Melving, 1984). According to Goldschmidt (1997) the designer needs to search and generate a large amount of additional information in order to represent the problem including the definition of its goal states, and to build channels that connect them. Since design problems are quite complex, inaccurate and singular, successful solutions cannot be predicted beforehand (Suwa et al, 1999). This is one of the reasons why dealing with design problems requires high levels of creativity in addition to a lot of commitment and refined skills.

Design problems appear to be ideal for the study of creativity due to the outstanding significance and relevance of creativity in design. However, the definition and assessment of creativity in design problem solving have not been appropriately acknowledged up to now. There are few if any theoretical approaches to this issue, and almost no empirical studies supporting them. Some investigations on design creativity focused on the designer (Barron and Harrington, 1981), and a few dealt with the design process (e.g., Lawson, 2004). However, a theoretical approach supporting the assessment and definition of design creativity requires further elaboration. Creativity in design is most often assessed in terms of an all-inclusive appraisal, grounded in the agreement among experts or authorities in the field of study. Although experts usually share a common view on the subject of evaluation, the variables, conditions and methods used to perform the assessment of the design stay for the most part biased, skewed, and fuzzy.

This study suggests an approach for establishing the assessment of design creativity with respect to design products and design processes on the basis of variables that are amenable to objective evaluation. Creativity in design has been defined in terms of a number of factors dealing with: fluency, flexibility, elaboration, innovation, usefulness, aesthetic skills in design representation, fulfillment of design requirements, and reference to context. These factors will be used for guiding expert designers in defining and assessing individual creativity in architectural design.

The first part of the paper will present a general background about creativity, design creativity, and the assessment of design creativity. Then an empirical study about the assessment of design creativity is presented. Eight factors are considered for defining design creativity and evaluating the design of architectural students. The next section is devoted to presenting conclusions about the definition and assessment of creativity in design. The major finding was that the evaluation of creativity in design relates mainly to innovation. Although some other factors were found to be important features of design, these did not correspond to the evaluation of creativity.

Creativity

Creativity is viewed as one of the most mysterious, intriguing and little understood aspects of human thinking (Hsiao and Chou, 2004). Creativity is often referred to by means of fuzzy terms, such as a part of intelligence that differentiates human beings from the other animals (Goldenburg and Mazursky, 2002), or a synthesis of new and old ideas by means of a drastic restructuring and re-association of them (Heap, 1989). Creativity is also defined as the ability to communicate extraordinary thoughts, to affect perception of reality in a critical way, to contribute to original inventions or discoveries (Csikszentmihalyi 1997), and to generate novel ideas for solving complex problems (Franken 2001). The act of thinking creatively involves perceiving situations from new perspectives, a change that improves solving routine problems (Coyne, 1997). Koestler (1964) suggested differentiating between routine and creative thinking in dynamic terms. While the former functions within a unique situation or framework, the latter is constantly activated by considering simultaneously a system of relationships between several contexts. Creative thinking involves a capacity to explore a variety of unconventional methods for exploring numerous innovative solutions (De Bono, 1977).

When creativity is put into practice for assessing individuals, four factors that have been defined and operationalized by Guilford (1981) and others (Torrance 1974) are generally considered. These four factors are fluency (defined as the total number of relevant responses), flexibility (defined as the different categories of relevant responses), elaboration (defined as amount of detail in the responses) and originality (defined as the statistical rarity of the responses). The current study uses these factors as a part of the procedure for assessing design creativity.

Creativity in Design

Design is a complex domain that requires innovation. The success of a design output depends not only on the skills and capacity of the designer, but also on her or his level of creativity. Similarly to product or industrial design, architectural design is a non-routine problem-solving activity that relies strongly on human experience, knowledge, and to a large extent on creative thinking (Hsiao and Chou, 2004)

Creativity in design has been studied in relation to both the design process, and the designer. Creative design process is characterized by the exploration of a large number of solutions extending beyond the designer's own knowledge (Gero et al.,1988). Of particular importance in the first stages of designing is the process of searching for design alternatives which has a positive effect in expanding the range of design ideas. Explorations in a metaphorical search space enable the designer to inspect more concepts and ideas, which enhances the chances for attaining satisfactory and unexpected solutions (e.g., Cross, 1997; Gero, 2000; Lawson and Loke, 1997).. The exploration of different kinds of ideas, and their impact on the design process were studied by Goldschmidt and Tatsa (2005) in the context of the design studio. The findings were that a body of richly interrelated good ideas represents the essence of creative and innovative design processes. Idea exploration, the perception of a problem as a whole rather than in small parts, and the ability to produce abstractions to map relationships between different domains were found by Candy and Edmonds (1996) to constitute the core of the creative process.

A study that focused on the personality of designers showed that one difference between creative and non-creative designers consists in that the former strive to attain an artistic standard of excellence, whereas the latter try only to comply with standard values (Mackinnon, 1965). In another investigation the creativity of the designer was defined by the capacity to take risks to challenge the unknown (Hanna and Barber, 2001). Further, some of the characteristics of creative designers were found to be: verbal fluency, strong motivation to achieve individual goals, impulsiveness and spontaneity, risk taking, tendency to identify new problems instead of dealing with old ones, playfulness, freedom of assessment, flexibility, ability to establish interconnections between unrelated domains, intelligence above the average, selfishness, a definite need to be original, and eagerness to succeed in their disciplines (Barron and Harrington, 1981; Candy and Edmonds, 1996).

Assessment of Design Creativity

In recent years there has been a resurgence of interest in the question of what is the assessment of creativity about. The issue of how individuals assess creativity has come to complement more conventional questions about the nature of creativity and its determinants that have dominated the research agenda in creativity (Bergum, 1975; Bull, and Davis, 1982; Khatena, 1975; Khatena and Torrance, 1976). The notion of assessment of creativity has particular importance in the domain of design, and indeed still needs more clarification. While major concerns of some studies are the definition of design creativity, the promotion of creativity in design, the role of creativity in the design process, the development of tools for supporting creativity, or the study of the personality of designers, investigations dealing with an objective assessment of creative design are still missing. What are the methods and criteria to be considered for evaluating design processes and design outcomes is up to now less than clear. In general, creativity is assessed through a comprehensive evaluation typically performed by design experts. The main deficiencies of this modus operandi are evident: first, it is not easy to decide who is a valid evaluator; secondly, evaluation is basically charged with an appreciable dose of subjectivity and bias; and thirdly, controlling the evaluations and the procedures for establishing criteria needed for evaluations is quite controversial. An instructive case in point is the evaluation of students' design projects carried out by design studio teachers at the end of the course. The average grade set by teachers during the evaluation process frequently reflects the level of success reached by students. Even though teachers may agree on the overall quality of a design project, the approach and parameters on which assessments are supposed to be founded remain an unsolved issue, difficult to determine and manage.

Creativity Factors

The four factors of creativity proposed by Guildford (1981) (fluency, flexibility, elaboration, and originality) are highly relevant and frequently used as a framework for performing objective assessments of individual creativity in different contexts and domains. Since the goal of the current study was to assess individual creativity in architectural design (referring to both the design process and the design output), we found it adequate to implement this basic set by the following four additional variables: (i) mastery of aesthetic skills for design representation (e.g. Christiaans 2002), (ii) functionality, also termed usefulness (e.g., Franken, 2001), (iii) extent of fulfilling the actual design requirements (e.g. Weisberg 1993; Eckert et al 1999), and (vi) reference of the design to the physical context.

A difference has been made between fulfilling the design requirements and reference of the design to the physical context in order to emphasize the importance of the latter in the design process. It may indeed be considered as defining the problem domain of the design task since the physical environment is the locus where a channel of metaphorical communication or dialogue between the design object and its immediate context is established. A successful relationship between the product (viz. building, street or square) and its context is an essential implicit requirement of creativity in regard to architectural design.

Study Objectives

The first objective of this study was to examine whether expertise judgment of creativity in design is a reliable and valid method of assessment. The second objective was to unify procedures of assessment in order to evaluate objectively the creativity of design individuals, and design products. We attempted to learn about the relative importance of each of the eight factors of creativity, and. their relative degree of their representation in the assessment of architectural design. The third objective was to validate this procedure by means of correlations between the objective evaluations of design carried out through the use of the creativity factors, with the overall evaluation of design creativity.

Method

Fifty two students of architecture, from the first to the fifth year of studies, participated in the study. All were administered the design task. They were supplied with ten A3 numbered sheets of paper, and requested to use them for consecutive drawings in the course of designing. They were asked to present graphic solutions through the different stages of the design process. The students were provided with a task sheet presenting the problem and containing general instructions accompanied by a schematic map of the area (See Figure 1).

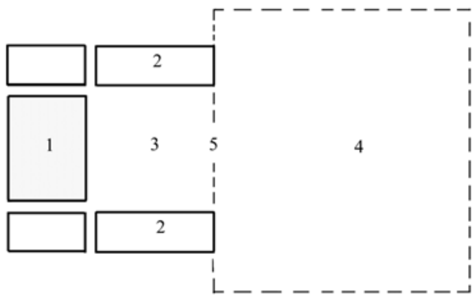

Figure 1. Schema illustrating the urban context for the design task.
1. Town Hall; 2. Dwellings; 3. Square; 4. Park; 5. Area available for the design of the museum.

The problem called for the design of a small museum to promote the cultural development of an historical village. The museum had to be located between an old Town Hall of over 100 years old, and a neighboring natural park. One of the constraints of the problem was to attain a creative design solution that establishes a successful dialogue with the urban context. The specifications called for implementing the following major functions of the museum: a gallery area for the location of sculptures, an exposition area for the display of pictures and posters, a main room for the presentation of key lectures and seminars, an area for administrative tasks, a small coffee-shop, and spaces for general services. In addition to the generation of a high-quality design solution, the participants were requested to present all the graphic material produced during the design process. The design session lasted approximately two hours.

Four architects (with at least 10 years of experience) were asked to evaluate independently each design in line with the specific variables (see Table 1 for a detailed list of the variables). The assessments of the design solutions were carried out by the architects without any information about the goals of the study. The solutions were coded to preserve the identity of participants and guard confidentiality.

Illustrations of a Design Solution by a Student

This section presents the main stages of the design process of an advanced student that participated in the empirical study. The main design concept consisted in designing a museum that could connect the Town Hall and the Park by an underground path. The student commented:

"Instead of designing a museum detached from its context, I am trying to produce an open-to-the sky space. This part of the museum is integrated with the urban path connecting the Town Hall with the public green area. "

During the design process, the student explored the possibility of designing a building that will establish a dialogue with the context to make a differentiation between the civic character of the Town Hall square, and the natural park, while attempting to strengthen the relation between the two urban elements. While producing his first sketches, which included some diagrams, a plan, and a section drawing (see Figure 2), the student wrote:

"The museum is organized around a main axial street. It [the street] is defined by a row of trees belonging to the natural park, and an elevated bridge that connects the museum with the Town Hall square. "

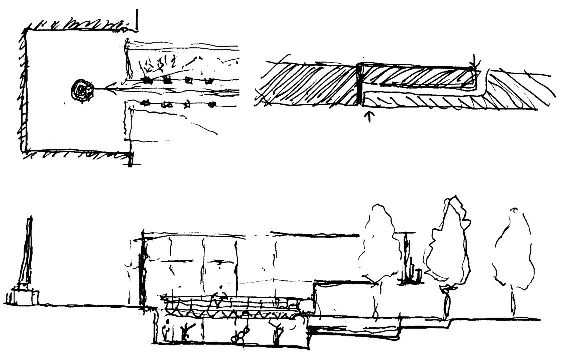

Figure 2. First sketches produced by a student for the museum problem.
(a) Schema of two elements connected through an upper and a lower floor plan;
(b) plan and section of the Town Hall square, the natural park, and the split museum connecting both sides of the town by means of an elevated bridge.

In the last stages of the process, the idea of a bridge integrated with the museum was developed. The elevated street allowed establishing visual relations with an underground patio, and a physical connection between both sides of the museum. Figure 3 illustrates a section drawing which shows the spatial relationship between the bridge-street and the different split-levels of the museum. Figure 4, on the other hand, is a general plan of the museum and its relationship to the urban context. The two wings of the museum are gradually rotated in their relative direction to the main axis of the building. On one side they open to the park, inviting nature to come inside the building, and on the other side they make a gradual transition to the Town Hall building. The final design solution was considered to be successful, and received a high grade for its level of creativity.

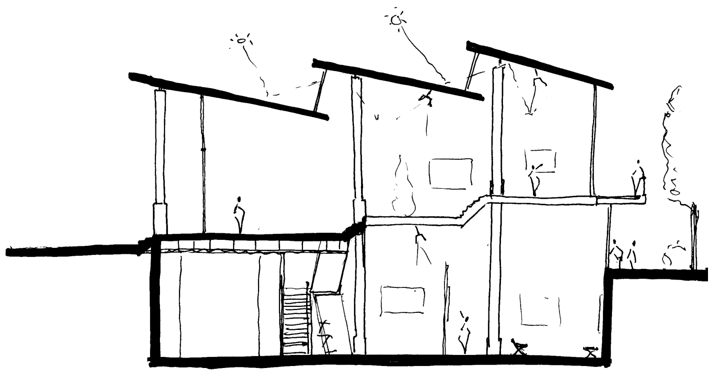

Figure 3 Final sketches produced by a student for the museum problem.
Bridge-street, and its vertical relationship with the park and the square.

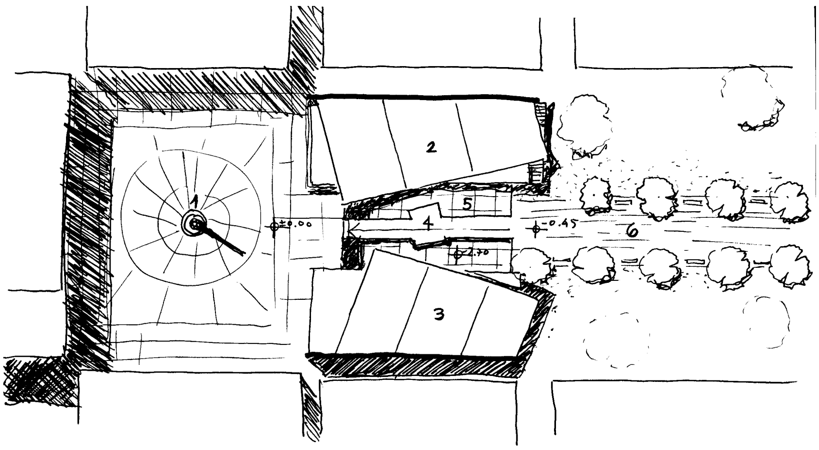

Figure 4 Final sketches produced by a student for the museum problem.
General plan of the museum and its string relationship to the urban and natural contexts.

Results

The analysis of the assessments by the experts was carried out in a sequence of four steps. The first step consisted in checking the degree of correspondence between the four architects with respect to each criterion individually. This was done by means of a reliability procedure, whereby the scores of the four architects that acted as referees were considered as items in a scale. Table 1 (column 4) shows that the reliability coefficients were in each case very high. Therefore, it is considered valid to merge the scores assigned by the referees for each individual participant in each of the variables. Consequently, means were computed through the four assessments for each variable for each participant. After that, interrelations between different criteria for the same variable were examined in order to check the option of combining these criteria when they referred to the same kind of variable. This option was adopted when the criteria were intercorrelated positively, significantly and sufficiently highly. Accordingly, the two criteria of the variable 'fluency' were combined (Pearson Product-Moment correlation r=.618), and the four criteria of the variable 'usefulness' were combined (Cronbach's alpha was high r=.912). As a result, the initial list of variables was reduced to 8 variables. The third step consisted in applying factor analysis to the 8 variables (See Table 2). Three valid factors resulted from this operation, as is indicated by their eigenvalues (>1.00) and the percents of variance for which they account (>5.00%). In addition, the graph of the Scree test (See Figure 5) shows that there is a notable decline of the eigenvalues of the extracted factors from the fourth factor onward. This supports the stability of the first three factors and the statistical justification for considering only these three factors. The first factor accounts for 41.60% of the variance and has high saturations on the variables of 'usefulness' and 'fulfilling demands of the task'. Consequently, the first factor was labelled 'practicality in design'. The second factor accounts for 20.76% of the variance and has high saturations on the variables of 'innovation' and 'mastery of skills concerned with design aesthetics'. Therefore, it was labeled 'innovation in design'. The third and weakest factor accounts only for 15.29% of the variance. It has high saturations on' fluency' and 'flexibility'. This last factor was labeled 'dynamism in designing' in view of the role of 'fluency' and 'flexibility' in the dynamic processes of designing. Since saturations in the range of .50 to .70 may be interpreted as signifying potentially medium contributions, it may be concluded that the variable of 'elaboration' contributes both to the first and the second factor, and that the variable of 'reference to the physical context' contributes to the second factor.

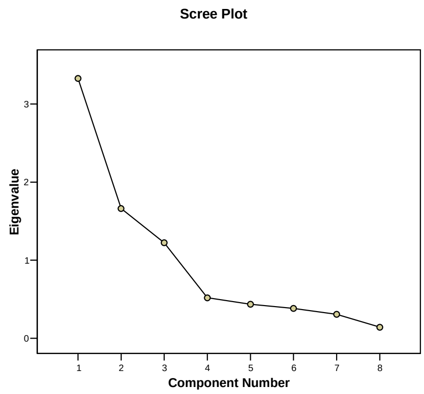

Figure 5 Scree test illustrating the eight design factors as indicated by their eigenvalues.

In the fourth step of data elaboration correlations were computed between the three factors yielded by factor analysis and the evaluation of overall creativity. Only one correlation was significant and this is the correlation between the second factor (innovation) and creativity. The other correlations are non-significant (See Table 3).

Table 1. Means, standard deviations and reliability coefficients of the variables assessed by the architects

Variable and criteria of assessment used by referees	Mean	Standard Deviation	Reliability (Cronbach's Alpha)
Fluency (No. of filled pages)	6.021	2.14	.997
Fluency (No. of distinct units of information)	14.814	6.94	.979
Flexibility (No. of alternative solutions)	.935	.918	.777
Elaboration (No. of features included in the design, e.g., stairs, thickness of walls; furniture. A total of 20 features presented)	9.041	3.11	.888
Usefulness, functionality A (Clarity of function of each component in the design) [rating on 5-value scale]	2.752	1.179	.808
Usefulness, functionality B (Efficiency of functioning of the design) [rating on 5-value scale]	2.457	.951	.824
Usefulness, functionality C (Availability of all the drawing plans according to the presented drawing sections) [yes/no response]	.33	.422	.652
Usefulness, functionality D (Degree to which the design may be realized in reality) [rating on 5-value scale]	2.67	1.059	.773

Usefulness, functionality: Overall	2.503	.902	.916
Innovation value [rating on 5-value scale]	2.645	1.082	.758
Fulfilling specified design requirements [rating on 5-value scale]	3.67	1.162	.865
Considering context [rating on 5-value scale]	2.562	.854	.839
Mastery skills concerning the aesthetics of the design representation [rating on 5-value scale]	2.69	1.141	.827

Table 2. Results of a factor analysis on the variables assessed by the architects[1]

Variables	Factor 1	Factor 2	Factor 3
Fulfilling specified design requirements	**.925**	.044	.037
Usefulness	**.924**	.232	-.006
Innovation	-.130	**.870**	.018
Mastery skills concerning the aesthetics of the design representation.	.434	**.759**	-.044
Reference of the design to physical context	.281	.690	.361
Elaboration	.543	.626	-.044
Fluency	-.001	-.045	**.869**
Flexibility	-.005	.145	**.868**
Eigenvalue of factor	3.328	1.661	1.223
Per cent of variance accounted for by factor	41.603	20.763	15.289

The numbers in the cells are saturations of the variables on each of the factors. The highest saturations that are considered for defining the factor are typed in bold.[2]

[1] The 5-value scales ranged from low ratings (=1) to high ratings (=5), each level of rating being described verbally

[2] The factor analysis was performed according to the principal components rotated varimax procedure after Kaiser normalization. For the purpose of the analysis, fluency was redefined in terms of an index (standardized z-scores) based on the two components of number of pages and number of information units (see table 1), and usefulness was assessed in terms of the overall variable representing usefulness A –D. Thus, the number of included variables was 8 (they are specified in the first column of Table 2)

Table 3. Correlation coefficients between the three factors resulting from the factor analysis and the evaluation by the expert architects of the overall creativity in the designs

	Factor 1	Factor 2	Factor 3
Correlation coefficient with evaluated creativity	-.055	767*	.084

* p <.001

Conclusions

The study dealt with exploring the possibility of grounding the definition of creativity in objective criteria in general and in the domain of architectural design in particular. Eight variables were considered for defining individual creativity in design. In addition to the four standard variables dealing with innovation, fluency, flexibility and elaboration proposed by Guilford (1981), we defined four additional ones dealing with: usefulness, mastery of aesthetic skills for design representation, fulfilling design requirements, and consideration of the provided physical context.

The four referees that evaluated the design outputs in terms of the eight variables and overall creativity showed a high degree of correspondence with each other. This finding confirmed that human judgment of creativity in design is a reliable and legitimate method of evaluation. This conclusion holds at least insofar as the assessment of a specific design product is based on variables defined by objective criteria, and is conducted by experts, in a specific domain such as architecture.

The correlation coefficients between the three factors, resulting from the factor analysis, and the evaluation by the expert architects of the overall creativity in the designs showed that the evaluation of creativity in design corresponds mainly to innovation.

This finding suggests that when one asks experts to evaluate design creativity, what they actually focus on is innovation. This is highly interesting from a theoretical point of view because in the domain of creativity there is an ongoing controversy about the definition of creativity: the two major components of creativity that are being discussed are innovation and operatibility (usefulness, utility). It seems that if one uses in research the common method of evaluations of creativity, one gets mainly information about one of these components but certainly not about operability. And operability is not the only aspect of creativity that is overlooked in overall evaluations of creativity. In general, it appears that the evaluations of creativity in design are based on a too narrow basis. If one want to get evaluations of components other than innovation, it is necessary to ask the design experts involved in evaluation to refer specifically to these other aspects, each separately. The implication is that for the evaluation process, experts are to be instructed or trained in considering broader aspects of creativity. Due to the narrow basis to which creativity evaluations refer, and since innovation too is

based on evaluations, it is not yet possible to overcome or obviate the need for evaluations by experts. The major thrust of this third conclusion is methodological.
As noted, the assessments of design creativity by experts do not correspond to other important components of creativity, such as usefulness, flexibility, fluency, and elaboration. The importance of these components is demonstrated by further results obtained from a factor analysis performed among the eight variables. This analysis revealed that the three dominant factors are 'practicality in design', 'innovation in design', and 'dynamism in designing'. The most dominant factor is 'practicality in design' representing the variables of usefulness of the design and extent of fulfilling the design task requirements. Another unanticipated result is that the factor of 'innovation in design', representing the originality of the design and the mastery of skills concerned with the aesthetics of design, turned out to be only the second factor in terms of the variance it accounts for, and hence its importance and salience. The result which identified innovation as the second factor is unexpected insofar as innovation is commonly considered as the very core of creativity, as has also been confirmed by our previously cited high correlation obtained between innovation and creativity.

Further, also the finding that practicality is a stronger factor than innovation is unexpected. The role of practicality in design has remained unclear. Traditionally innovation has been assumed to be the most remarkable aspect of creativity, but findings of studies showed that creativity has to do not only with original ideas, but also with usefulness and practicality (Franken, 2001; Weisberg, 1993). Yet, surprisingly, usefulness was not considered by Guildford (1981) as a relevant factor in assessing individual creativity. The stress on practicality may perhaps be manifested more in architecture than in other kinds of art endowed with much more restricted functionality. On the other hand, the ordering of the factors could mirror the relatively low level of innovation in the participants of this study. Therefore, the relatively higher importance of practicality over innovation observed in this study could be viewed as reflecting either the characteristics of the sample of participants in our research, or the essence of creativity in architecture.

The finding that the variables of innovation, and skills needed to represent and communicate an idea graphically were strongly related deserves a comment. Proficiency in the use of representation tools might play a significant role in the generation, refinement, and communication of creative ideas in design.

The third and weakest factor was 'dynamism of designing' representing the variables of flexibility and fluency. It is well-known that flexibility requires specific skills in order to tackle a problem situation from a diversity of viewpoints. The weak contribution of this variable to design creativity may be due to an incapacity of students that participated in the study to explore a large number of alternative solutions before attaining the final design. It may be hypothesized that participants in the study embarked too fast and hence too early on developing a single design solution, before searching other alternatives. This may have had two immediate consequences. The first one is that students were not so fluent in generating a large quantity of graphic information, which may have enlarged the opportunities to reflect on the design problem. The second one is that reducing a universe of potential design solutions to a unique alternative may have reduced the level of innovation of the final solution. Of course, time constraints assigned to the study may have also affected the chances to reflect on the design task, and to consider more than a single solution.

The variables of elaboration and reference to the physical context were found to have the lowest contribution to creativity. The graphic representations produced during the design task had a high esthetic value. However, they were very schematic, and as such lacked a satisfactory level of detail and information. It remains an open question whether the assignment of additional time would have contributed to enhancing the elaboration of the design output, and whether under different circumstances this variable might prove to contribute to the assessment of creativity.

In the future phases of this research project, current findings will be analyzed in further contexts. The dominant factors of design creativity will be explored in relation to cognitive and motivational aspects of the designer.

Acknowledgments

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