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Principles of flexibility in design process, with the approach to creativity in design

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Abstract

In recent decades, the design in various fields has undergone remarkable changes that many theoreticians have tried to define and present new models to promote efficiency or provide more creativity during a design process. But most of the time, designers have to apply processes that are restricted to fixed and repetitive steps, unchangeable copy, or an adaptation of what they have learned from other designers during education in the past. From the authors' point of view, one of the main issues is how the design process can sufficiently be flexible to be used in all situations. The concept of flexibility is the capability of being used by both experienced and novice designers or architects, the ability of adaptability to unpredictable conditions and time changes, and the ability to avoid fixed and unchangeable steps. In this article, according to library resources, it has been endeavored to disclose six general principles as a flexible framework for design which has crucial effects on the development of creativity in the design process. Based on Delphi's methodology, the suggested principles are assessed by 20 experts to approve the profound impact of them on improving design process creativity and flexibility. By using these principles and based on the strategies of architects, a wide variety of flexible design process can be organized.

Keywords
Design process, Design thinking, Flexible framework, Creativity, Delphi method.

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1. Introduction

It has been stated that "design research is a bridge between the descriptive and analytic nature of science and the need for an innovative change in teaching practices" (Augustsson, 2018, p.1). A specific design process is not capable of being an efficient prescription for all aspects of a design or being all-inclusive for every individual. For instance, if a teacher teaches a design process to students, it is not clear that all of them can be successful in their design projects. Certainly, there will be differences in students' abilities, contexts as well as the inherent nature of design projects (Van Aken, 2005). As a consequence, the flexibility of each design process is a useful and unique factor. When designers encounter a complicated topic, they probably just know about the totality of the final results. Therefore, they should differentiate between challenging projects which need new approaches to deal with, and conventional problem-solving (Dorst, 2011; Roozenburg and Eekels, 1995).

Novice designers in a wide variety of fields, often select and get accustomed to a specific design process with respect to their interests, experiences, and also under the influence of educational methods in their academic centers. Historically, the design was handed down from generation to generation verbally or implicitly. Also, all artifacts and artificial environments have gradually developed (French, 1994). Having dealt with open complex problems, pioneer designers always preferred to create a framework in their field of practice (Dorst, 2011). Some designers take the design process into account as an intuitive and unjustifiable process; many appraise it as a rational process, and some other designers regard it as an unconscious process.

Regardless of having different ways, the common point between all design processes is to have specific frames in the design method. Van Aken (2005) argued that traditional process design might no longer be answerable to large, complex, and creative design. Because of the inefficiency of the prescriptive design process, a few numbers of design processes with determined steps do not have enough potential to generate exceptional and creative outcomes. In today's world, designers should possess organized mental skills to produce novel and valuable ideas (Johnson and Indvik, 1992; De Bono, 2006). To be creative in design practice, Mahmoodi (2001, p.111) asserted that two fundamental factors should be regarded: "the creative people and creative approaches of dealing with a design problem" that should regard.

In the meantime, top designers perceive planned and helpful strategies that will lead to a specific value to address a complex problem. These strategies involve the development or adoption of a framework (Dorst, 2011). Experienced designers attempt to maintain, develop, and manage the organized frameworks that can adapt to various levels of design practices (Dorst, 2009). Many designers would prefer to employ different strategies during their design process to reach relevant design solutions in a way that this practice will provide flexibility in using all steps of the process. A design process is a guideline to keep designers on the right track (Mahmoodi, 2001). The strategies and principles, as accelerants in the design process, enable designers to refrain from design-by-habit conditions and help them to adopt creativity in problem-solving (Broadbent, 1973; Mahmoodi, 2001).

2. Research context

In this section, this article contributes to a better understanding of the procedure of the creative design process and to an approach to develop the process through analyzing the nature of design knowledge, creativity in design, and design thinking. By combining these three discussed records, the article has a specific orientation towards complex design projects. The present research was conducted based on the information collected via previous research and qualitative records. The aim is to develop a flexible framework for the design process with an intense focus on creativity and design thinking during the process that can be useful for students and designers. The concept of flexibility is the ability of the changeability in the design process in a way that it can be used by both experienced and novice designers, the ability to be adaptable to unpredictable conditions and coordinated with

time factors in design, and the ability which avoid predetermined thinking and fixed or unchangeable steps. To do so, first, the history and necessity of the design processes and their specifications are discussed. Subsequently, based on the literature review, six principles related to increasing flexibility and creativity in the design process will be presented. Then, the Delphi technique will be employed for evaluating the effects and validity of the principles on a design process. In this method, the opinions of experts will be asked to achieve consensus on the proficiency and impact of our arguments.

2.1. Design and its process

On the whole, the design focuses on how things must be accomplished, but natural sciences are about how phenomena are. The difference between design and scientific techniques indicates that the design process is a method showing how things are created (Idi and Khaidzir, 2015; Goldschmidt and Smolkov, 2006). Every decision during the design process can have a direct impact on the efficiency of the project during construction and utilization (Othman and Abdelwahab, 2018). Recently, the design process has been more complicated, and the computer software has presented more and more details about the productions. Nevertheless, this case cannot guarantee its high-quality. A myriad of scholars in various fields has done investigations on the nature of design activity to decipher the design process and introduce it as an appreciation, teachable and, debatable phenomenon (Cho, 2017).

Since the first conference on design methods which has been held hitherto, the purpose of scholars has been to improve the process and results of production. They have made an effort to reach a fixed framework of the design process and its activities (Kowaltowski et al., 2010). For the first time in 1971, French declared a design model with four major phases. Since then, other intellectuals have tried to propose similar linear methods (French, 1998). Though it is beyond the scope of the present paper to explore the details and dynamics of these models, it should be noted that there was intricate disagreement among researchers and theoreticians about the structure of the design process (Goel and Pirolli, 1992). Some believed in a linear process, but others argued that there are co-evolutionary iterations between the progression of researching and reaching from problems to solutions (Maher and Tang, 2003).

Regardless of all, it is generally agreed that a specific organized procedure cannot be repeated for all aspects just for the reason that it was appropriate before (Ozsoy, 2007). The nature of the design process is not a linear sequence of predetermined actions (Chiaradia et al., 2017; Kowaltowski et al., 2010). "Recognition that design is not simply a linear process is seen as a significant milestone in the development of design process theory" (Green et al., 2014, p.528). Overwhelming regularity and restriction of primary models may lead to prevent designers from free progression in design procedures or surpass them from having the freedom of action. In recent decades by rejecting linear theories, designers avoided exerting invariable and cumbersome regulations. Most designers prefer to apply the creative process instead of inflexible ones. While designers need to know the characteristics of a flexible design process rather than a fixed process as a prescription (Van Aken, 2005), they often employ individual viewpoints that are informal to solve wicked problems (Kowaltowski et al., 2010).

"Experienced individual architectural or engineering designers, or small teams of them, tend to use informal procedures for their design processes, which they have developed over time through their initial professional training and through subsequent experimenting and learning" (Van Aken, 2005, p.383). This kind of attitude in the design process can be categorized as an evolutionary and conventional design (Dorst and Cross, 2001; Van Aken, 2005). In the recent process design, some principles should be observed to gain valuable outcomes which most important of these principles are non-linear activities without fixed timing, the ability for interactions and explorations based on designers' thoughts, and also undetailed and large process steps depending on the progress of the design

projects (Roozenburg and Eekels, 1995; Van Aken, 2005) which are consistent with the definition of flexibility. So, designers should regard process design as one of the main parts of a design, not as an optional one for starting the process. It is one of the striking differences between conventional design and evolutionary design (Figure 1). In this case, designers should be aware of the main principles of the design process that bring flexibility; therefore, they will be able to arrange and personalize it. They will have more flexibility in determining which features of the process to be accepted and which ones to ignored (Goel and Pirolli, 1992).

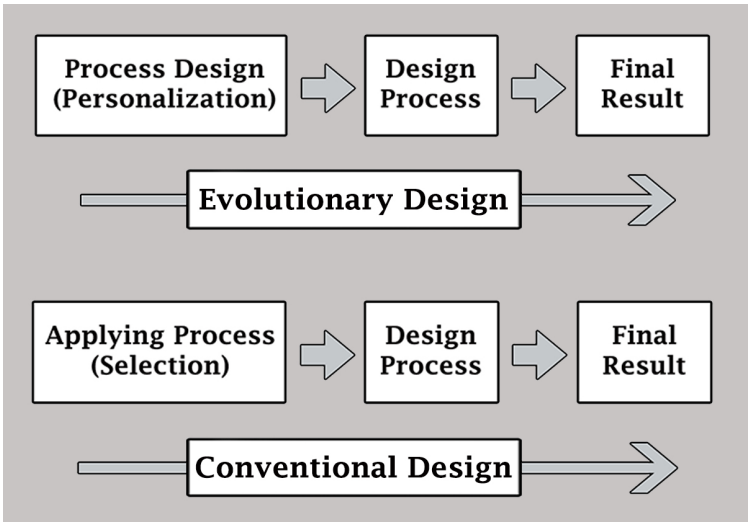

Figure 1. *Difference between the process of conventional design and evolutionary design.*

2.2. Creativity in design

When the results of an idea became original, operational, and novel, then we can define creativity (Elton, 2006; Amabile et al., 1999). In many sciences, we can succeed through analysis and description; even so, they are not enough in design. Designers need imagination and synthesizing to find novel situations of problem-solving. There is even a gap even between design and pure art because design is related to the implementation of predetermined functions for users (Williams et al., 2010; Alexioua et al., 2009). Therefore, without considering the function and utility in design, creativity will not be made. It is commonly referring to creativity to the four main domains in researches: creative process, creative product, creative person, and creative environment (Howard et al., 2008). In this article, it will be attempted to study several perspectives related to process and product, not person and environment.

As the engineering design process has numerous similarities to the creative processes (Howard et al., 2007), creativity is the cornerstone of design and an integral part of the engineering design process (Danaci, 2015; Amabile, 1996). It is a broad term that means abilities or skills for solving problems with a new notion. (Cho, 2017). Taura and Nagai (2013) described creativity in design as a value in which ideas will be conceptualized. In this context, they discussed two kinds of creativity. "The first is related to the process of designing, whereas the second is related to the products that represent the outcomes of the first" (Eilouti, 2018, p.181). As experiences of designers have a profound impact on how to utilize a design process or change its procedure to fulfill innovation and creative results (Couger, 1995), creative performances in process of design are under the influence of several factors namely individual abilities, use of technology, nature of decision task and, the level of experience or prior practices of designers (De Bono, 2006).

Creativity enables designers to overcome irrational thinking and reach new levels of efficiency and satisfaction. By innovative solutions, creativity is a powerful tool to work out problems (Daemei and Safari, 2018) and produce unique ideas to improve life (Rahmann and Jonas, 2010). Casakin (2007) discovered that creativity allows designers to search for new concepts and ideas to solve wicked problems by surpassing common domains. So, to face complex and unusual design, creative skills require a flexible design process, adaptable thinking, risk-taking, and the acceptance of openness in the process (Boden, 1991). Some considered creativity as a factor in outcomes and products (Antoniades, 1992). Others categorized it as a process of design (Seggern, 2008). The term 'fixation' which often resulted from prior knowledge includes some types of obstacles that can impede insight. It is said that fixation can prevent more creativity (Smith, 1995). The majority of fixations occur in the early of a design process, whereas it some-

times could be started in all stages. So, we need to produce innovation and ideation at every step of the process (Crilly and Cardoso, 2017).

Cognitive sciences illustrated that there is not timing and pattern for production of creativity because it relates to the mentality of every designer (Rahmann and Jonas, 2010). Antoniades (1992) asserted that the base of creativity is the relationship between fantasy and imagination in reality, so they need artistic (uncertain) and scientific (quantitative) views together. Limited conception and imagination in repetitive and inflexible frameworks will not result in not obtaining a suitable output of creativity, either scientific or non-scientific. A distinct design process must possess the flexibility to react in various conditions, create acceptable and innovative outcomes, challenge previously accepted ideas to reach new and valuable results, and also be adaptable enough to lead designers toward creativity (Gero, 2000; Dorst and Cross, 2001; Crilly, 2015).

2.3. Design thinking

Design thinking is a new paradigm for facing dilemmas in many design practices. This term is used by Rowe for the first time in his book in 1987 (Dorst, 2011; Rowe, 1987). "Design thinking can also be defined as how a designer sees and how s/he consequently thinks" (Akpinar et al., 2017, p.151). Some researchers conspicuously illustrated that the study of the human mind and thinking process help to understand the facts of the design process (Lawson, 2006). In a design project, to analyze and synthesize and evaluate the obstacles, designers should benefit from thinking skills (Mahmoodi, 2001). Flexible thinking was required to avoid fixation and attain creativity (Crilly, 2015) because design thinking has different shapes in nature (Roy and Brine, 2013). The scholars asserted that design strategies should contain two different phases of decision making: sequences of decisions in analysis, synthesis, and evaluation on the one side, and detailed design-oriented stages on the other side (Lawson, 2006). These two spaces should have mutual capabilities, so each phase needs a distinct mentality.

As a matter of fact, a design process is a dual approach divided into two continuous negotiations: problem-solving with cognitive abilities and concept generation with intangible elements (Nagai et al., 2009). Although these two types of approaches are against each other, both are complementary. These dual dimensions of thinking between problem and solution, which no one can define without the other one, will continue to achieve the goals. This feature does not indicate any starting and finishing points and does not follow the direction of going from one predetermined action to another (Lawson, 2006). Creative achievement stems from the result of two types of mental processes: generative (in solution space) and exploratory (in problem space). To produce new concepts, designers apply divergent thoughts in generative mode. On the other hand, in exploratory mode, they apply convergent ways of thinking to compare the concepts with rational principles and conclude appropriate answers (De Bono, 2006).

Maher in 1994 proposed co-evolutionary design as a new mechanism in problem-solving of design via two separate dimensions that affect each other. The model includes two dimensions for the problem in parallel with design solutions (Maher, 2001). Another characteristic of the co-evolutionary model is the relation between problem requirements and available solutions in two different spaces. In this two-way interaction, firstly the transitions will be evaluated concerning to alterations of problems and then concerning to solutions' changes (Maher and Tang, 2003) (Figure 2). "The focus of the search is based on the problem requirements when searching the solution space and based on the solutions when searching the problem requirements space" (Maher and Tang, 2003, p.48). The variables transfer from the problem category to the solution category and vice versa, in which the flexibility of the design process will be improved. In each stage, some of the problems will be solved and, some new requirements will appear. Then designers find more requirements for solutions and change the previous one to shape final results

regularly. The transitions will continue until outcomes include solutions for all problems or at least a high percentage of them (Maher and Poon, 1996; Maher and Tang, 2003).

3. Results and discussion

Design of design-process means to organize the design process. In practice, some designers intend to employ general or total approaches for process design. Nevertheless, professionals usually use a specific design process which is a copy or adaptation of a previous one with some changes according to the context of a new design, analyzing formal features, and prescriptive design knowledge (Van Aken, 2005). Also, the role of creativity and innovation cannot be denied. Designers use mental imaginary as a tool to present novel ideas and solutions. They evaluate and change the mental image to figure out challenges (Idi and Khaidzir, 2015).

To understand the complex nature of the design process, we should realize that they have been developed in response to rectify a specific problem or a special need (Dorst, 2011). In this article, flexibility or adaptability are our requirements. A versatile design process should adequately be manageable, flexible, and adaptable so that it can encounter a series of problems and make a correct context for designers to generate various kinds of solutions (Van Aken, 2005). Based on our definition of flexibility in the previous section, it helps the design process to be appropriate for numerous designers with different personalities and futures because its levels are changeable enough to be manageable. In this case, designers will possess freedom of action in thinking, time management, expression of creativity, and decision making. This characteristic adapts to unpredictable conditions and avoids fixed steps in the design process. According to the aforementioned materials, literature review, and assessments, a flexible design process which formed on the designer's demands, project requirements, and unexpected conditions should have some principles. These extracted principles can be categorized into the following features:

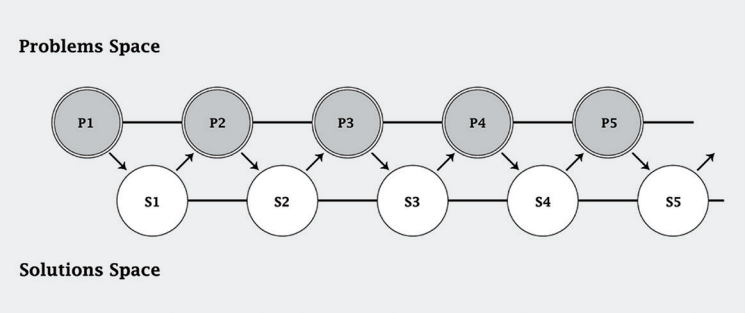

Figure 2. *Sweep between two spaces in the co-evolutionary design.*

1. Primary insight: Usually, the first phase of the design process for all participants is fuzzy and vague. And the high percentage of fixation happens in the early stages of a design process (Crilly and Cardoso, 2017). Designers often go into the design process with this phase, which does not have a distinct time frame and can help them to concentrate on problems, interests, and similar previous contrivances. Also, it provides the necessary time to review all aspects of challenges and more development on primary initiatives. Hence, this stage is an inevitable part of the process (Khurana and Rosenthal, 1997). In this stage, individuals use their content thinking based on acquired knowledge. During this phase, they apply information learned during educational courses, professional work experiences, or gained from the environment in their life (Mahmoodi, 2005). This part of the process helps designers to follow new notions with a creative mind to avoid repetitive solutions which have seen formerly.

2. Dual space process: The design process can be divided up into two inverse spaces: problem-oriented space and solution-oriented one. Design problem solving can be multipurpose based on this distinction (Goel and Pirolli, 1992; Kroes, 2002). Indeed, the design process as a compound process contains two distinct categories of intellectual activities to avoid predetermined thinking or unchangeable steps. This is one of the criteria of flexibility. The first intellectual activity is a conscious mental activity which is about logical reasoning and rationality of the designer by concentrating on problem requirements. The second is unconscious mental activities related to the creative abilities of a designer to the solution's requirements and features (Mahmoodi, 2005; Maher

and Tang, 2003; Abo et al., 2016). In the first part, designers applied different types of thinking based on analysis and logic, which help to aware of problems: Critical thinking, Serialistic thinking, Reflective thinking, and Convergent thinking. In the second part, their thinking is according to a holistic and intuitive approach that helps to create innovative solutions: Creative thinking, Holistic thinking, Impulsive thinking, and Divergent thinking (Mahmoodi, 2005; De Bono, 2006). Designers must figure out design-related problems to create efficient solutions and eliminate current problems. Cognitive theory during the first part of the design process is obligatory to innovate and solve problems in the second part (Kalin and Barney, 2014). This feature of flexibility in design process causes intellectual freedom for designers.

3. Iterative approach: Regarding unexpected and perplexing conditions during the design process of new challenges, designers must be prepared to apply flexible and new strategies to solve the dilemma ahead (Kowaltowski et al., 2010). Because when creativities associated with the project are developing, the designers are not aware of all the imminent opportunities, circumstances, or forthcoming problems. In the meantime, design thinking requires new attitudes toward the process. So, examining the problems and approaches toward solutions need to review during the design process (Roberts et al., 2006). Design thinking also needs new viewpoints and reactions during the process. When problems are appraising from several aspects, we can avoid partial attitudes and wrong results. Accordingly, the iterative design process assists designers to modify probable existing problems or develop solutions (Roberts et al., 2006). They have many chances to review problems and solutions from different aspects and apply the required changes.

4. Holistic approach: Design steps are not deterministic rules or essential propositions for the determination of circumstances or relationships. They are substructures for guiding design operations (Broadbent, 1973). It would be better to follow a simple procedure in complex product design processes and have relatively no detailed steps in an overall framework (Lessio et al., 2009). These processes are not designed for robots, and during the process, the designers themselves should organize and control some details (Van Aken, 2005). To diminish the restriction of a design procedure, and to guarantee freedom of action in design for both experienced and novice designers, the design process should have an adjustable framework in order to allow them to apply changes in their thoughts during the design process and it cannot be based on overly deterministic steps. Rather it should just show an outline or a general policy of the process to keep its flexibility.

5. Open-ended process: "There is no natural end to design process" (Lawson, 2006, p.55). Designers never can claim that it is the final solution or result. They stop the process when the time is up, or there are no new ideas in their mind to continue with, or they think the result is valid for the target user group. This is the definition of time flexibility that provide better personalized time management for designers. It is a skill for designers to realize a suitable solution for their design, which can gain this experience by practices. Consequently, the end of the problem-solving process is not a specific point but a specific bound. The radius of the bound can be defined depending on the individual situation and time (Lawson, 2006; Chiaradia et al., 2017).

6. Elastic process: Top or experienced designers to deal with complex challenges prefer to use much more systematic and efficient strategies and normal regulations which they have developed and adapted over time. In this case, they will create creative and useful outcomes. (Dorst, 2011; Van Aken, 2005). Regarding the differences between a young designer and an experienced one, based on their practical knowledge, skills, promptitude, and their experiences, the amount of their efforts and intellectual distance from problem-solving is completely different (Van Aken, 2005). In this case, the starting point of design processes and the needed time to complete design will be varied. As a consequence, the process must enjoy the flexibility to be used by all types of designers on the manner of starting the process from the closer or farther point

of the final solution.

As pointed out above, the six principles in a design process can improve the flexibility of the process, increase the chance of creativity, and enhance freedom of action for users. In the following, the authors purpose to evaluate the validity of the claim. As the Delphi technique can be used for qualitative research that is exploratory to identify the nature and fundamental elements of a phenomenon (Habibi et al., 2014), it is selected for this article. The main aim of the Delphi technique is to acquire the dependable consensus of a group of experts' opinions about a topic by a series of questionnaires combined with controlled feedbacks (Dalkey and Helmer, 1963). In this respect, one of the most important phases in the Delphi technique is the selection of eligible members as a panel who are aware of the knowledge and expertise of the studied subject. These people are known as the Delphi panel. According to the number of the panel, Dalkey (1971) asserted that it would be sufficient to involve more than 10 persons as a group of specialists in every Delphi study. Also, Delbecq et al. (1975) and Ludwig (1997) recommended that it will be better if the number of experts in the panel is between 10 to 20 experts.

Accordingly, in our study, 20 experts in various fields of design from top-ranked universities in Iran were chosen. To select the members of the expert panel, Zainudin (2012) introduced some criteria that have been considered in this research such as the number of papers that have been published in journals and international conferences, their publications' productivity, and citation impact (h-index), and their level of education (Irdayanti et al., 2015). This assessment has been accomplished in three rounds. In this manner, we sent a questionnaire including a description of the questions, aims of the research, and an explanation of the six principles through E-mail to the members of the panel. After taking their feedbacks in the first and second rounds and consider their opinions on the features and nature of the principles, the consensus was obtained in all sections after the third round. It was a five-point Likert scale (Habibi et al., 2014) so that each expert could rate each principle from 1 to 5, whether paying attention to this case in design process enhances the flexibility and creativity or not (Every rate, in turn, represents to what extent an expert either agree or disagree with the statement: 1: Extremely disagree/ 2: Disagree/ 3: Neither agree nor disagree/ 4: Agree/ 5: Extremely agree). The average of the rates (Table 1) for each principle was more than 4 which approves the consensus of experts on the application of principles. It means, experts have accepted that these features of the design process can result in the growth of flexibility and adaptability of the process, the creativity of designers, and their freedom of action during the design. In the third round of Delphi techniques, the highest point was for the second principle (4.65) and the minimum averages were for the fourth (4.15) and the third (4.2). The rest principles had middle positions with 4.5, 4.4, and 4.3 rates. Also,

Table 1. *The rates of experts to the principles in the third round of the Delphi method.*

Principle	Extremely disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Extremely agree (5)	Average
First (Primary insight)	0	1	1	7	11	4.40
Second (Dual space process)	0	0	1	5	14	4.65
Third (Iterative approach)	0	0	4	8	8	4.20
Fourth (Holistic approach)	0	2	2	7	9	4.15
Fifth (Open-ended process)	0	0	2	6	12	4.50
Sixth (Elastic process)	0	2	1	6	11	4.30

none of the experts extremely disagreed with the principles. The rate of each principle from 1 to 5 and the average rates of them are provided in Table 1.

4. Conclusion

A design process can be defined as a framework of a changeable organization or as holistic instructions for the process of creation. It is a human-oriented system toward creativity, made for the broad spectrum of designers, and not for robots, to produce creativity. Therefore, the process of producing creativity cannot be defined by some continuous fixed and immutable phases. By reduction in changeless steps and decreasing the details, as well as an increase in flexibility of the process in different situations, the efficiency of the design process, will improve. A flexible design process provides many advantages most notably for compatibility of the process with time schedules (start point and endpoint), topic features and question's specifications, rules of design thinking, and the most important of all, the designers' abilities, thoughts, and knowledge. The application of given six principles in the discussion (Primary insight, Dual space process, Iterative approach, Holistic approach, Open-ended process, Elastic process) as an overall framework of the flexible design process can develop compatibility and as a result, creativity. The principles promote freedom for designers to act during their works, as though they can shape details of the design process in complex and unpredictable circumstances based on their strategies and thoughts in design. To approve the accuracy of the constructive impacts of the principles, based on Delphi techniques, the opinions of 20 experts in this field were asked. Finally, at the end of the third round of this method, all came to a consensus. It was a firm conviction of the vast majority of experts that using these principles during the design process resulted in improvement of the mentioned criteria, including flexibility and adaptability of the process, freedom as well as creativity of designers. It is noteworthy that these statements and their elaborated theoretical knowledge can be supported more in future researches with some original and practical design studies such as a comparative analysis of novice and experienced designers' processes under the influence of applying the principles. These principles can be examined through case studies research in academic design studios to determine the amount of the values of each principle on the efficiency of students on their design projects.

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