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Effect of Creative Thinking Techniques on the Designer and the Product in the Creative Architectural Problem-Solving Process; (Problem Finding to Problem Solving)

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ABSTRACT

Today, the possibility of facing problems for which there is no predetermined solution in architecture has increased. Therefore, trying to bringcreativity into problem solving is always vital. The main purpose of this research was to measure and evaluate the effectiveness of the intervention of creative thinking techniques in the creative architectural problem-solving process. The present study is practical in terms of purpose. The research method is an experimental with a pre-test and post-test design with an experimental and control group. Finally, the data were analyzed using ANCOVA, MANCOVA, and Bonferroni post hoc statistical tests using SPSS 25 software. The results of data analysis between experimental and control groups show a significant and positive effect of creative thinking techniques on two levels: 1) problem solving creativity and presented solutions, fluidity (F=21.96 and P=0.0001), expansion (F=3.49 and P=0.05), initiative (F=27.31 and P=0.0001) and flexibility (F=9.88 and P=0.001); 2) Creativity in design product (P=0.0001 and P=41.07). Also, the results of the Bonferroni test to examine the pairwise difference show that among the creative thinking techniques, paradigm breaking technique have more effective results than the paradigm *stretching* and paradigm preserving techniques (mean difference=0.004 and 25.02). By using creative thinking techniques in the he process of solving architectural creativity, it is possible to achieve the growth and promotion of components of creativity (fluidity, expansion, initiative, flexibility) in designers and provide creative solutions in the process of solving architectural problem, which will ultimately result in the design product in the three areas of physical, function and semantic. Also, in the process of solving creative architecture, as we move from paradigm preserving techniques to paradigm breaking techniques, the amount and level of creativity (the solver and the presented solutions-design product) increases.

Keywords: *Architectural Design Process, Creative Problem solving, Design Problem, Stimulation of Creativity*

1. Introduction

Creativity is considered a valuable asset and a necessary resource for humans in the 21st century [1] and is used as a powerful tool to improve the quality of life [2]. It should be noted that in today's world, the probability of encountering problems for which there is no predetermined solution has increased. Therefore, solving a new problem requires creativity [3]. In addition, creativity also requires sensitivity to the problem and the ability

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to redefine it, including brain transfers, reinterpretation, and breaking free from activity fixation to drive unique solutions, which should always be taken into account [4]. Therefore, this phenomenon in the current competitive environment and full of issues and problems [5], should always be examined and the conditions for its improvement should be provided [6] because the survival and excellence of any society depend on the amount of attention and importance to the emergence and expansion of this ability According to [7], three types of creativity produce new ideas. The first type is hybrid creativity, which can use familiar ideas to generate new ideas. The second type is exploratory creativity, which can generate a new idea by exploring structured concepts. The third type is transformative creativity, which changes some dimensions of structures to emerge with a new structure. Therefore, exploring and transforming a conceptual space to create creativity [5], if we classify creativity into three categories: individual creativity, creative process, and creative products [8]. Individual creativity, which is clear is not a fixed characteristic and can be strengthened or weakened under the influence of factors. Torrance believes creativity can be developed and promoted [9]. Therefore, to improve the creativity level, we need training based on creativity techniques. The creative process also focuses on the processes that the creative person follows to make the production of a creative product possiblility and the techniques of stimulating creativity to clarify this process [8], among which, creative products refer to the usefulness and novelty of result of an idea and can include a tangible product such as tools and inventions or an intangible product such as design One of the reasons for students' difficulty in designing and solving the problem is that they are simply asked to participate in a learning technique that may not be based on their skills and abilities [10] and perhaps if the conditions for the emergence of creativity in them are provided correctly, many times more effective results will be obtained .Therefore, it should be noted that many techniques can stimulate creativity. Creativity can enter the problem-solving process through these techniques (problem-finding to problem-solving) and subsequently have different results. These techniques are divided into three categories by the paradigm or space governing the problem: paradigm preserving, paradigm stretching, and paradigm breaking techniques.

All human abilities, including creative solution of architectural problems, can only be realized in the shadow of education [11]. The essential characteristic of a human is the ability to learn [12]. Based on this, in order to promote creativity, among the various methods to stimulate and improve creativity, it has gone to stimulating methods; among each of the proposed categories and its techniques, one technique has been selected and measured and evaluated, because the present study aimed to find the answer to this basic question: Can the use of creative thinking techniques increase the components of measuring and evaluating the creativity of the problem solver (fluidity, flexibility, initiative, expansion) and the designed product in the architectural problem solving process? In this regard, research hypotheses have been provided at two levels (designer) and (design product): 1- The intervention of creative thinking techniques in the architectural problem-solving process effectively promotes the designer's creativity level, i.e., the components (fluidity, expansion, initiative, flexibility). 2- There is a difference between the effectiveness of each creative thinking technique in measuring and evaluating the components of creativity (fluidity, expansion, initiative, flexibility). 3- The intervention of creative thinking techniques in the architectural problem-solving process is effective in promoting the level of creativity of the designed product. 4- There is a difference between the effectiveness of each creative thinking technique in measuring and evaluating the creativity of the designed product.

2.Research background

In recent years, many studies have been conducted on the importance of developing creative thinking ability and its cultivating, so that strengthening creative thinking skills has been prioritized [13]. In many studies, developing and strengthening of creative thinking has been considered necessary [14]. It can be said that many research findings have proven the effectiveness of creative thinking techniques and their stimulation in developing problem- solving and creativity skills through its useful functions and facilitating communication between solutions and ideas [15] because they have reported that through them, problems and experiences that require a causal system can be easily presented to new students. Some of the studies related to the present research are as follows:

Research findings of Kolubinski et al [16] showed that creativity could be improved through various interventions. Kashani et al [17] in a study entitled how to improve the level of creativity in students found that by taking into account the level of intelligence and the talent level, suitable creative thinking techniques such as the Scamper technique can be used to improve creativity. Cheng [18] in examining the effectiveness of creative thinking techniques and their stimulation, concluded that the most important method for improving people's creativity level is the brainstorming technique, which is superior to other techniques for improving creativity, including innovation and storytelling. The findings of Ghadam Pour et al [19] showed that idea-seeking (Scamper) and brainstorming techniques significantly increase creativity compared to traditional methods.

Nevertheless, it is worth noting that, unlike the brainstorming technique which leads to an increase in creativity in the short term, more time is needed to see the effectiveness of the idea-seeking method. The findings of Yaghobi et al [20] showed a significant difference in the effectiveness of creative thinking techniques. The research findings of Badri Gargari & Kalavani [21] showed that creative thinking techniques increase creativity in fluidity, flexibility, initiative, and expansion and increase creative thinking . The findings of AlMutairi [22] stated that with the techniques to stimulate creativity through group participation and brainstorming together in a group, solutions can be found, in addition, creativity can be increased. The findings of Poon et al [23] reported that the primary use of the Scamper technique is based on individual ideas seeking which can be very effective for groups; its purpose is to cultivate the power of imagination and visualization. The findings of Mobini et al [24] showed that teaching problem-solving skills significantly increases the creativity of engineers. The findings of PirKhaifi et al [25] stated that the review of creativity research indicates that creativity in the combination of its main elements (fluidity, flexibility, initiative, and initiative) has increased under the influence of teaching creative thinking techniques, especially initiative ability has a significant jump. The findings of Sharifi & Davari [26] examined and compared the effect of creativity cultivation methods in increasing creativity and the results showed that none of the creativity cultivation methods is superior to the other. However, regardless of the method, it helps to develop creativity. In this regard, the findings of Hosseini-nasab & Lotfollahi [27] showed that there is no significant difference between creative thinking techniques. In general, based on what was said, it can be stated as follow: Even though many studies have been conducted on the effectiveness of creative thinking techniques and methods of stimulation, and most of them have an effect on it, there has been no detailed research comparing paradigm-preserving, paradigm-stretching, and paradigm breaking techniques.

Table 1: The relationship between the findings of previous studies and the present study.

No	Source	Findings of previous studies
1	Al-Zu'bi et al,(2017); Fazylova & Rusol, (2016)	The creative thinking techniques act in the role of facilitating the communication of ideas and solutions.
2	Kashani et al, (2017)	Paying attention to individual intelligence and talent in applying creative thinking techniques is influential in its effectiveness.
3	GhadamPour et al, (2017)	Time is influential in the effectiveness of creative thinking techniques.
4	Cheng, (2017)	The brainstorming technique is an essential technique to improve creativity.
5	Shen et al, (2016)	Simplifying problems requires causal systems, which are possible through creative thinking techniques.
6	Henriksen et al , (2016)	Improving the ability to solve problems by using creative thinking techniques.
7	AlMutairi, (2015)	Providing creative solutions by benefiting from creative thinking techniques.
8	Poon et al, (2014)	The role of creative thinking techniques in individual idea seeking and their effectiveness in the group
9	Kolubinski et al, (2018); Badri Gargari et al, (2013) Mobin et al, (2010); PirKhaifi et al, (2009)	The role of creative thinking techniques is influential in improving creativity components.
10	Davari, (2009) & Sharifi	Lack of superiority of creative thinking techniques compared to each other.

3. Fundamentals and theoretical framework of research

3.1. Creativity

A historical review of the subject of creativity shows that during the1950s, there was a greater interest in education of creativity. The implicit assumption of those actions was that creative personality and mind could be shaped by education. In1950, a range of measures was done to stimulate the creativity; however, the activities

of that time lacked a regular and controlled program . A work of the 1950s should be considered the first responsible measure to encourage creativity cultivation programs [21]. Creativity is one of the most complex and excellent manifestations of human thought, which effectively develops human civilization [1]. Creativity is one of the predictors of people's wisdom. All the success and progress of people depend on their fertile, dynamic, and effective thinking [28]. Derick defines creativity as using of mental ability to create an original idea or thought [29]. According to Saif, creativity is a product of one of the types of thinking called creative thinking, and it is the ability to think about things in new and unusual ways and reach unique ways to solve problems [30]. Osborn has proposed a comprehensive view of the creative thinking process and believes that the creative thinking process includes of three main stages. These stages include1. Truth-seeking, including problem and preparation, 2. Idea seeking: including creating ideas and their cultivating, 3. Problem solving: including evaluation and selection [31]. Guilford is also one of the most prominent psychologists who has conducted many studies in the field of creative thinking; he has expressed four characteristics to measure creative thinking. In Guilford's theory, creativity is defined as divergent thinking; he believes that divergent thinking consists of several characteristics of fluidity, flexibility, novelty, expansion, combination, analysis, and organizing complexity [32]. According to Torrance, creativity means feeling a problem, disagreeing about information, guessing, hypothesizing about these deficiencies, evaluating and testing guesses and hypotheses, modifying and retesting them, and finally relating the results [33]. According to Torrance (1974), creativity has four dimensions: fluidity, initiative, flexibility, and expansion. According to a scientific theory, creativity means producing something that is new and novel, useful, relevant, and suitable for a specific task [34]. It should be noted that although the ability to be creative is innately deposited in human existence, its flourishing requires cultivation [35]. Since creativity is considered the main factor of progress and development in society, it becomes more important to pay attention to creating a suitable platform for its cultivation cultivating creativity as a necessary skill for development in today's era is undeniable [36]. Also, cultivating creativity should be one of the goals of architectural design. So, cultivating creativity in architecture should be considered one of the main components of architectural education.

3.2. Creativity and problem solving

Creativity is one of the most outstanding cognitive abilities and an example of the most beautiful manifestations of divergent thinking; this particular feature plays an essential role in innovation and problem solving [37]. Problem solving is a common aspect of the creativity in any process, which is also one of the basic principles of design. Here, the creative process is described as a sequence of thoughts and actions that lead to original and pure products [38]. Psychologists consider problem -solving skills essential to human ability and capability, and believe that humans are continuously solving problems throughout their lives [39]. Creativity is a process that involves problem solving, conceptualization, ideation, creating of artistic forms, and theorizing [40]. Each step of the problem solving process has a unique task or goal These steps include defining, formulating the problem, preparing a list of solutions, making decisions, applying solutions and evaluating the results of the solutions [41]. According to Simon, architectural design is also a process based on problem solving where the designer's primary skill is to search for significant problems, identify the framework in a context, and design a creative solution. To accompany creativity, this skill requires defining the problem space in such a way that it forms the overall structure of the design [42]. In such a case, the problem space provides an abstract and mental representation of the desired solution, which can propose a new solution by implementing the solution and the laws of change and transformation. The proposed solution is a product of applying the transformation rules of algorithms and discoveries on a series of consecutive intermediate solutions. The proposed solutions are also a product of repeaed evaluation of previous solutions and evaluation-based decisions, which can be considered as the result of abilities obtained through learning, practice and education [43]. At the same time, architecture also requires providing creative solutions and forming creative thinking. In this case, what is more important than architectural products is the path taken In such a case, the structure of the design will be so flexible and elegant that, along with the ability to use tools and a critical view, it will lead the architect to solve problems creatively [44].

It should be noted that there are two types of creativity in design from the point of view of origin; one is in the platform of the design process, and the other is focused on the design product [45], both of which are very influential in the overall design.

In general, regarding creativity, researchers and experts have several definitions from Ackoff & Vergara, Ariet, Gullford, Ghiselin, Kaiser, Atrick, Bazerman, Stein, Woodman, Franken, Koesteler, Kaiser, Ackoff & Vergara, Amabile, Koontz & Allen, Sternberg, Csikszentmihalyi, Cock, Weisberg, Luthans, Lussier, Handy, Lussier, Maslow, Torrance. Each of his/her definitions, under the influence of various factors, including the researcher's scientific field and the perspective, emphasizes creativity's aspects and dimensions. Therefore, it can be said that creativity is one of the complex, ambiguous and multidimensional words [46].

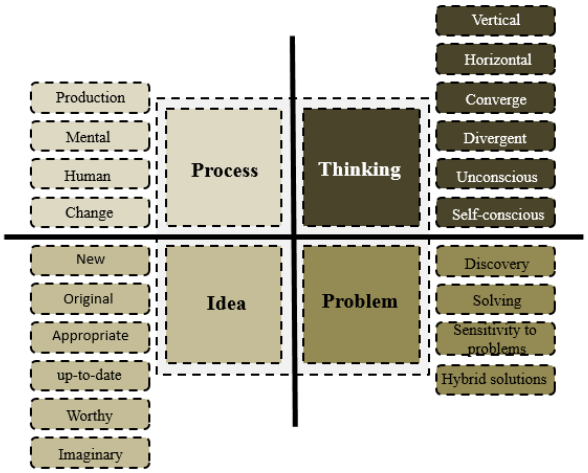

Figure. 1: Summary of the views of researchers in the presented definitions of creativity.

3.3. Creativity cultivation

According to most researchers, traditional education methods not only do not help develop creativity, but also prevent them from moving in this direction. Therefore, if professors create a suitable space as much as possible and use active and exploratory teaching methods in the classroom, they have helped new students to use their creativity Osborn [47] and Torrance [48] believed that all people can be more or less creative and the cultivation of brain abilities is the basis of creativity. Also, in this regard, De bono [49], found that for people's creativity, they should be taught the right ways of thinking, and in this way, all people will be able to show their creativity. Here, a question arises, which method is more creative?

In response to this question, studies generally show that researchers believe that creativity and creative thinking can be strengthened through techniques. These techniques can be depicted in a continuum from the desire to preserve the paradigmto break the paradigm, which the most important techniques are described in table (2).

Table 2: Creative stimulate techniques

Paradigm breaking techniques	Paradigm stretching techniques	Paradigm preseving techniques
Wishful thinking	Object stimulation	Brainstorming
Rich pictures	Metaphors	Brainwriting

Paradigm preserving technique: In these techniques, the opinions and views of the participants do not change the components and relationships between the components of the problem; that is, there is no change in the space governing the problem. Usually, these techniques limit creativity to minor developments in existing components and relationships. Such techniques mainly contain ideas with very little or no risk, and the power of imagination, intuition, and enlightenment are not used much in generating ideas. Using of these techniques does not necessarily require particular expertise, experience, or training; if the environment is favorable, all people can use them. Paradigm stretching technique encourages participants to develop problem space, ideas, and solutions. This is done by introducing a new element or interface into the problem or changing the relationship between the elements; paradigm stretching ideas occur. Paradigm breaking technique: In these techniques, participants are encouraged to break

the problem space and pursue and see something completely new, fresh and different. In this way, the space governing the problem is broken and completely new elements and relationships are presented. Among all these methods, three methods of brainwriting, topic stimulation and rich pictures have been measured and evaluated in this study. Brainwriting method: brainwriting is a technique similar to brainstorming in which group members are asked to write their ideas separately on paper and then exchange them among themselves, so that every one has an opportunity to learn about ideas. The goal of this technique is to generate lots of good ideas. Method of stimulating the topic: In this method, group members are encouraged to examine situations from different perspectives, which is presented to develop a list of topics that are completely unrelated to the problem. Rich pictures method: This technique helps people to look at the problem from different perspectives. In this regard, the group members are asked to write a brief sentence about the problem and draw two pictures about it; one is the person's picture of the existing situation and the other is the picture of the situation [50].

3.4. Conceptual model

The conceptual model of the present study emphasizes creativity stimulation techniques based on Mcfadzean's theory and Torrance's theory of creativity. In the conceptual model of the research, it is assumed that the methods of creative thinking and stimulation of invention creativity through entering into the creative problem-solving process (problem finding) to problem-solving have a significant contribution to improving the level of creativity in the three areas of Problem-solving, presented ideas and problem solving, and designed product.

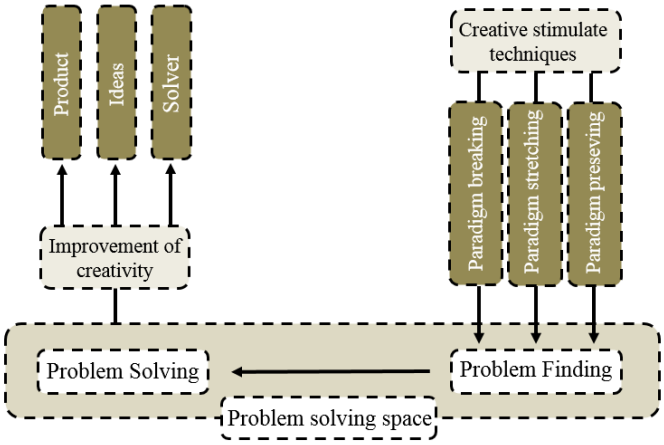

Figure. 2: Conceptual model.

4. Research method and data collection tools

The present research method was of a quasi-experimental type with a control group and in the form of pre-test and post-test. The reason for the quasi-experimental nature is the researchers' use of volunteer subjects. However, the allocation of subjects into experimental and control groups was done randomly. The random sampling method is effective in increasing the generalizability of the results. The statistical population includes all students in the first semester of a discontinuous B.Sc. degree in architecture who are studying at the Islamic Azad University in the second semester of 2021-2022. The present study is practical in terms of the purpose of analytical-descriptive by the nature of the method. In this study, the pre-and post-test plan with the control group consists of four groups of subjects. All four groups are measured twice pre-and post-test and in two theoretical levels of the Abedi creativity test to measure the level of individual creativity and the practical level of the design test to measure the invention of the design product. The first measurement is done by performing a pre-test and the second by a post-test. To form groups, the researcher uses random sampling to place the subjects in the experimental and control groups. The four groups formed in this way are similar, and measuring the dependent variable of creativity for all four groups is done simultaneously and in the same situation. The sample size is 20 people in four identical groups, 11 female students and 9 male students. In this study, the experimental group 1 gets exposed to the independent variable

(paradigm preserving techniques), the experimental group 2 gets exposed to the independent variable (paradigm stretching techniques), and the experimental group 3 gets exposed to the independent variable (paradigm-breaking techniques). The control group does not get exposed to the independent variable.

4.1. The following tools were used to collect data

Theory level

The tool used at the theoretical level of the creativity assessment questionnaire, which is known as the Abedi creativity test (CT), was made based on Torrance's theory about creativity by Abedi (2002). This questionnaire has 60 three-option questions, which consist of four subtests: fluidity, expansion, initiative, and flexibility; that is, in four parts of the questions, they examine the level of creativity.
1- The fluidity of thought, or in other words, mental fluidity
2- Expansion and the ability to generalize concepts and substitutions in affairs
3- The initiative and degree of different dissent in matters of creativity
4- Flexibility and the ability to accept things outside the background and mental assumptions.
Each item has three options that indicate low, medium, and high creativity levels. Questions 1 to 22 are related to fluidity, 23 to 33 to expansion, 34 to 49 to the initiative, and 50 to 60 to flexibility. The reliability of the Abedi creativity test was obtained through the retesting of students in 1984, including the reliability of the fluidity section: 0.85, initiative: 0.82, Flexibility: 0.84 and expansion: 0.80 [51]. Internal consistency using Cronbach's alpha for the subtests of fluidity, flexibility, initiative, and expansion on 2, 270 Spanish students were obtained at 0.75, 0.66, 0.61, and 0.61, respectively [52].

Practical level

The tool used at the practical level is the researcher-made questionnaire; the Delphi technique was used to extract the factors of measurement and evaluation of three experimental groups and one control group. It should be noted that when researchers are interested in a specific field or become aware of a difference of opinion in a specific field and want to examine the opinions of experts in that field and reach an agreement on it, free from a specific approach, and at the same time, they do not have enough sources and references to gather these experts in a meeting, the Delphi technique opens a way for experts to reach a consensus without the need for face-to-face interaction [53]. This technique is designed to sample a group of experts and to reach a consensus on a particular issue [54]. Also, university professors (4 experts in architecture) were used to extract evaluation factors. Since each of the professors considered several factors to evaluate the students' design products, it was necessary to categorize and summarize these factors first so that the product designed by the students could be evaluated. This stage was done using interviews and asking for their opinions. Then, a series of criteria were extracted using the Delphi technique, and finally, the professors were asked to give a score from0 to100 to each of the factors extracted from the Delphi technique. This measurement and evaluation has structural validity due to the interviewing and asking for opinions from experts, and it also has structural reliability due to the random sampling method. The studied factors extracted from the Delphi technique are summarized in three items: physical, functional, and semantic.

Instruction for performing tests

The way to perform the test is summarized in table (3).

Table 3: The way to perform the test.

group	How to select subjects	Experimental pre-test	Practical pre-test	Independent variable	Experimental post-test	Practical post-test
Experimental_1	Random	standard Torrance Creativity Test	Yes	Paradigm preseving techniques	standard Torrance Creativity Test	Yes
Experimental_2	Random	standard Torrance Creativity Test	Yes	Paradigm stretching techniques	standard Torrance Creativity Test	Yes
Experimental_3	Random	standard Torrance Creativity Test	Yes	Paradigm breaking techniques	standard Torrance Creativity Test	Yes
Control	Random	standard Torrance Creativity Test	Yes	-	standard Torrance Creativity Test	Yes

The above design shows these points. 1- Four subjects (three experimental and one control group) were randomly selected and replaced randomly and tested in the above design. 2- The experimental pre-test (Torrance creativity test) was performed for all four groups. 3- A practical pre-test was performed for all four groups. 4- The independent variable (paradigm preserving, paradigm stretching, and paradigm breaking techniques were performed for three experimental groups) but the control group did not receive any variable. 5- After performing the independent variable for the three experimental groups, all four groups were given a test (Torrance's creativity test) again. 6- After the test for all four groups, a practical test was conducted again for all four groups.

5.Findings

In this study, descriptive statistics tables and have been used for the statistical description of the research variables. Also, Univariate Analysis of Covariance (ANCOVA) and Multivariate Analysis of Covariance (MANCOVA) were used in line with the inferential analysis and testing of the research questions. In the conducted research, there were four groups of five people, including control, experiment 1, experiment 2, and experiment 3, Experiment group 1 (paradigm preserving), experiment group 2 (paradigm stretching), and experiment group 3 (paradigm breaking). The descriptive statistics of the research variables are reported in the following table.

Table 4: Descriptive statistics of research variables in pre-test and post-test

			Pre-test		Post-test	
Variable	**group**	**Number**	**average**	**Standard deviation**	**average**	**Standard deviation**
A total score of the practical test	Control	5	192/80	7/22	188	5/95
	Experimental_1	5	186/80	12/37	218/60	11/67
	Experimental_2	5	185/80	6/26	233/40	9/63
	Experimental_3	5	193/40	5/68	245/80	7/22
Semantic	Control	5	56/40	3/04	55/80	2/77
	Experimental_1	5	58/20	4/02	68	3/93
	Experimental_2	5	61/40	2/70	71	2
	Experimental_3	5	64/40	3/36	77/60	4/21
Function	Control	5	67	4/41	65	3/08
	Experimental_1	5	62	7/89	73/40	4/87
	Experimental_2	5	61/60	3/84	79/60	4/61
	Experimental_3	5	64/40	3/97	82/60	4/50
Physical	Control	5	69/40	2/70	67/20	2/28
	Experimental_1	5	66	4/06	77/20	4/86
	Experimental_2	5	62/80	5/35	82/80	4/08
	Experimental_3	5	64/60	5/02	85/60	3/04
Fluidity	Control	5	24/40	3/04	22/60	2/88
	Experimental_1	5	25	2/91	31/04	4/03
	Experimental_2	5	24/20	5/35	34	3/53
	Experimental_3	5	26/20	1/64	39/20	2/16
Expansion	Control	5	16	1	16/80	1/92
	Experimental_1	5	14/60	2/70	15/20	3/03
	Experimental_2	5	17/80	1/09	16/80	2/68
	Experimental_3	5	16/40	1/34	20/20	1/30
Initiative	Control	5	17/60	2/07	17/40	3/36
	Experimental_1	5	17/60	2/07	22/60	1/34
	Experimental_2	5	19/40	2/40	25/40	2/07
	Experimental_3	5	19/80	2/86	29/40	0/54
Flexibility	Control	5	14/20	1/48	14	1/87
	Experimental_1	5	13/80	0/83	16/40	1/14
	Experimental_2	5	14/80	1/30	17	1/87
	Experimental_3	5	15/40	1/14	20/40	1/14
A total score on the creativity test	Control	5	72/20	6/18	70/80	6/72
	Experimental_1	5	71	1/58	85/60	3/64
	Experimental_2	5	76/20	4/14	93/20	2/04
	Experimental_3	5	77/80	2/28	109/20	2/28

According to Table 4, the creativity score and its components in experimental group 3, has the highest mean compared to the control group and experimental groups 1 and 2, so it can be said descriptively that it was a more effective method. Among the reported variables, the total score of the practical test was also higher in experiment 3 than in other groups.The highest and lowest mean of creativity test in the post-test stage was observed in experiment 3 (with a mean of 109.20) and the control group (with a mean of 70.80), respectively, and also the highest and lowest mean of practical scores in the post-test stage was observed in experiment 3 (with a mean of 245.80) and the control group (with a mean of 188), respectively.
In the following, the first MANCOVA test was used to study (hypotheses 1 and 2). Before examining the research hypothesis, it is necessary to examine the presuppositions of using covariance analysis. The model error in each of the components of fluidity, expansion, initiative and flexibility follows a normal distribution (z=0.11 and p=0.20), (z=0.17 and p=0.11), (z=0.18 and p=0.06) and (z=0.11 and p=0.20). The assumption of the equal variance of model errors in each of the components of fluidity, expansion, initiative, and flexibility (F=1.27 and p=0.31), (F=1.5731 and p=0.23), (F=0.09 and p=0.96) and (F=0.83 and p=0.49) is accepted. The significance level of the box test and the equality of covariance matrices have also been established (F=1.25 and p=0.16). Now, after examining the presuppositions of covariance analysis, in order to examine the mean difference between the control group, experiment1, experiment 2, and experiment3, the MANCOVA test has been used, and results of this study are presented below.

Table 5: The results of the covariance analysis of the post-test scores of the total variable after modifying the pre-test scores

Source	Variable Post-test	sum of squares	Degrees of freedom	Statistics F	Significance level	Eta
Modified model	Fluidity	792/76	7	14/09	0/0001	0/89
	Expansion	102/28	7	3/40	0/03	0/66
	Initiative	421/84	7	23/82	0/0001	0/93
	Flexibility	115/39	7	7/17	0/002	0/80
Constant value	Fluidity	20/75	1	2/58	0/13	0/17
	Expansion	12/23	1	2/85	0/11	0/19
	Initiative	0/09	1	0/03	0/84	0/003
	Flexibility	2/23	1	0/97	0/34	0/07
Fluidity Pre-test	Fluidity	40/54	1	5/04	0/04	0/29
	Expansion	16/36	1	3/81	0/07	0/24
	Initiative	2/55	1	1/01	0/33	0/07
	Flexibility	0/04	1	0/01	0/89	0/002
Expansion Pre-test	Fluidity	0/69	1	0/08	0/77	0/007
	Expansion	0/04	1	0/01	0/91	0/001
	Initiative	1/38	1	0/54	0/47	0/04
	Flexibility	0/50	1	0/22	0/64	0/01
Initiative Pre-test	Fluidity	0/06	1	0/008	0/93	0/001
	Expansion	5/55	1	1/29	0/27	0/09
	Initiative	1/55	1	0/61	0/44	0/04
	Flexibility	0/41	1	0/18	0/67	0/01
Flexibility Pre-test	Fluidity	5/42	1	0/67	0/42	0/05
	Expansion	15/41	1	3/59	0/08	0/23
	Initiative	14/13	1	5/58	0/03	0/31
	Flexibility	5/37	1	2/34	0/15	0/16
Group	Fluidity	529/50	3	21/96	0/0001	0/84
	Expansion	45/01	3	3/49	0/05	0/46
	Initiative	207/28	3	27/31	0/0001	0/87
	Flexibility	68/17	3	9/88	0/001	0/71
Error	Fluidity	96/43	12			
	Expansion	51/47	12			
	Initiative	30/35	12			
	Flexibility	27/55	12			

Based on the results of the table, since the significance level of the group factor in fluidity (control, experiments 1, 2, and 3 groups) (p=0.0001 and F=21.96) has decreased from the significance level of 0.05, it can be said that different groups have a significant effect on the fluidity component of the experimental test. Also, the effect size value of 0.84 indicates the fact that about 84% of the fluidity score changes are due to the effect of the technique used and the significant level of the group factor in the expansion (control, experiments 1, 2, and 3 groups) (p=0.05 and F=3.49) is equal to the significance level of 0.05. It can be said that different groups have a significant effect on the expansion component of the experimental test. Also, the effect size value of 0.46 indicates the fact that about 46% of the expansion score changes are due to the effect of the technique used and the significant level of the group factor in the initiative (control, experiments 1, 2, and 3 groups) (p=0.0001 and F=27.31) is less than the significance level of 0.05; it can be said that different groups have a significant effect on the initiative of the experimental test. Also, the effect size value of 0.87 indicates that about 87% of the initiative score changes are due to the effect of the technique used. The significant level of the group factor in flexibility (control, experiments 1, 2, and 3 groups) (p=0.001 and F=9.88) is less than the significance level of 0.05; it can be said that different groups have a significant effect on the flexibility component of the experimental test. Also, the effect size value of 0.71 indicates that about 71% of flexibility score changes are due to the effect of the technique used. Bonferroni post hoc test was used to answer the question of which groups differ from each other.

Table 6: The results of the Bonferroni test analysis

Variable	group	Mean difference	Standard error	Significance level
Fluidity Post-test	Exp 1 – Control	-8/41	1/89	0/005
	Exp 2 – Control	-11/66	2/14	0/001
	Exp 3 – Control	-16/26	2/07	0/0001
	Exp 1– Exp 2	-3/24	2/47	1/00
	Exp 2– Exp 3	-4/60	1/97	0/23
	Exp 1– Exp 3	-7/84	2/27	0/02
Expansion Post-test	Exp 1 – Control	1/001	1/38	1/00
	Exp 2 – Control	0/05	1/57	1/00
	Exp 3 – Control	-3/35	1/51	0/22
	Exp 1– Exp 2	-0/95	1/80	1/00
	Exp 2– Exp 3	-3/60	1/44	0/16
	Exp 1– Exp 3	-4/56	1/65	0/10
Initiative Post-test	Exp 1 – Control	-5/83	1/06	0/001
	Exp 2 – Control	-6/70	1/20	0/001
	Exp 3 – Control	-10/05	1/16	0/0001
	Exp 1– Exp 2	-0/87	1/38	0/001
	Exp 2– Exp 3	-3/35	1/11	0/06
	Exp 1– Exp 3	-4/22	1/27	0/03
Flexibility Post-test	Exp 1 – Control	-2/85	1/01	0/09
	Exp 2 – Control	-2/52	1/01	0/28
	Exp 3 – Control	-5/82	1/14	0/001
	Exp 1– Exp 2	-0/32	1/32	1/00
	Exp 2– Exp 3	-3/30	1/05	0/05
	Exp 1– Exp 3	-2/97	1/21	0/18

In the fluidity component, a significant statistical difference has been observed between the control group and each of experiments 1, 2, and 3. Also, there is a significant difference in this component between the experimental groups 1 and 3. By examining the means, it can be concluded that experiment 3 was more efficient, but no significant difference was observed between experiments 2 and 3 in the fluidity component. In the expansion component, no significant statistical difference was observed between different groups and it can be stated that different techniques had no significant effect on the expansion component. In the initiative component, there is a significant difference between all the groups except the group of experiment 2 and experiment 3. The most significant effect was observed in experiment 3, then in experiment 2, and then in experiment1. In the flexibility component, a significant difference has been observed between the control group and experiment 3 and experiment 2 with experiment 3. In the following, the first ANCOVA test was used to study (hypotheses 3 and 4). Before examining the research hypothesis, it is necessary to examine the presuppositions of using covariance analysis. In order to examine the homogeneity of the slope of the regression line, according to the statistic F=0.94, in the grouping variable* pre- test practical creativity and the significance level of 0.44, the homogeneity of the slope of the regression line is established. The model error follows a normal distribution (z=0.10 and p=0.20), and the assumption of equal variance of the model errors is accepted (F=1.31 and p=0.3). Now, after examining the presuppositions of covariance analysis, the ANCOVA test has been used to examine the mean difference of the control groups, experimental 1, experimental 2 and experimental 3 and the results of this study are presented below.

Table 7: The results of the covariance analysis of the post-test scores of the total variable after modifying the pre-test scores

Source of changes	sum of squares	Degrees of freedom	Mean squared error	F	Significance level	Eta
Modified model	9433/63	4	2358/40	30/83	0.0001	0/89
Constant value	77/29	1	777/29	10/16	0.006	0/40
Pre-test	119/88	1	119/88	1/56	0.23	0/09
group	9425/47	3	3141/82	41/07	0.0001	0/89
Error	1147/31	15	76/48			
Total	9913/83	20				

Based on the results of the above table, since the significance level of the group factor (control, experiments 1, 2 and 3 groups) (p=0.0001and F=41.07) has decreased from the significance level of 0.05, it can be said that different groups have a significant effect on the total score of the practical test. Also, the effect size value of 0.89 indicates that about 89% of the total score changes of the practical creativity test are due to the effect of the technique used. Bonferroni post hoc test was used to answer the question of which groups differ from each other.

Table 8: The results of the Bonferroni test analysis

group	Mean difference	Standard error	Significance level
Exp 1 - Control	-32/57	5/75	0.0001
Exp 2 - Control	-47/70	5/82	0.0001
Exp 3 - Control	-57/60	5/53	0.0001
Exp 1- Exp 2	-15/12	5/53	0.09
Exp 2- Exp 3	-25/02	5/79	0.004
Exp 1- Exp 3	-9/90	5/88	0.67

Table (8) shows a significant difference between the control group and experiments 1, 2, and 3; also, there is a significant difference between experiment 2 and experiment 3. According to the mean difference column mentioned in the table, experiment 3 compared to experiment 2 and experiment 2 compared to experiment 1 had a more significant effect on the creativity score of the practical test.

In this research, first some descriptive indicators were reported for data description analyze, and according to the research method, the most appropriate test was covariance analysis. In order to use this test, it is necessary to establish assumptions such as the homogeneity of the slope of the regression line, the normality of the model error, and homogeneity (equality) of model error variance. So first the establishment of the above

assumptions was examined and reported, and then the results of covariance (ANCOVA) and Multivariate analysis of covariance (MANCOVA) were stated. The results of covariance analysis showed that there is a significant difference between the three experimental and control groups in the results of fluidity, expansion, initiative, and flexibility components (F=21/96, P=0/0001), (F=3/49, P=0/05), (F=27/31 and P=0/0001) and (F=9/88 and P=0/001). There is a significant difference between the three experimental and control groups in the practical test results (P=0/0001 and 41/07). Next, two-by-two comparisons between groups were made using Bonferroni post hoc test. The results indicated that among the intervention strategies in the practical test, experiment 3 showed more effective results than experiments 1 and 2 (mean difference=25/02 and 0/004), so that the lowest and highest score in physical components, function and semantics was observed in experiment 1 and the experiment 3, respectively. In the Theory test, the results of the Bonferroni test in the fluidity component, the intervention of experiment 3 are more effective than the experiment 2 (p=0/02 and mean difference=7/84); in the expansion component, no statistically significant difference was observed between the intervention groups; in the initiative component, the intervention of experiment 3 was more effective than experiment 1 (p=0/03 and mean difference=4/22) and intervention 2 was more effective than intervention 1 (p=0/001 and mean difference=0/87). In the flexibility component, experiment 3 was more effective than experiment 2 (p=0/05 and mean difference=3/30).

6. Discussion and conclusion

This study aimed to evaluate the effectiveness of the intervention of creative thinking techniques on the designer (factor) and the product in the creative process of architectural problem-solving. The first research hypothesis stated that the intervention of creative thinking techniques is effective in improving the level of the creativity of the problem solver including fluidity, expansion, initiative, and flexibility components of the problem. Results of the test of this hypothesis showed that creative thinking techniques including paradigm preserving, paradigm stretching, and paradigm breaking are effective on the creativity of students in the dimensions of fluidity, expansion, initiative, and flexibility and strengthen all four components of creativity. These results are consistent with the findings of Kolubinski et al, Shen et al, AlMutairi, Badri Gargari, et al, Mobin et al, and PirKhaifi et al, [15, 16, 21, 22, 24, 25]. The second research hypothesis stated that there is a difference between the effectiveness of creative thinking techniques in evaluating the components of problem-solving creativity including fluidity, expansion, initiative, and flexibility. The results showed that in each of the creativity components, a significant statistical difference was observed between the control group and each of the experimental groups. These results are in line with the findings of PirKhaifi et al, [25]. In response to the third research hypothesis stating that the intervention of creative thinking techniques improves the creativity level of architectural products, the results indicated the significant effect of the techniques on the total creativity score of the practical test. These results are consistent with the findings of Ghadam Pour et al, Cheng Poone et al, Badri Gargari et al, and PirKhaifi et al, [18, 19, 21, 23, 25]. The results of testing the fourth hypothesis manifested a significant difference between the control group and experimental groups. According to this hypothesis, creative thinking techniques differentially affect the creativity of the product design. These results support the results of Ghadam Pour et al, and Yaghobi et al's studies [19, 20]; On the other hand, they are inconsistent with the findings of Hosseini-nasab and Lotfollahi, and Sharifi and Davari [26, 27]. Results manifested that using creative thinking techniques in the creative architectural problem-solving process contributes to the growth and improvement of the components of creativity including fluidity, expansion, initiative, and flexibility in designers. Further, based on the results, such techniques provide creative solutions in the architectural problem-solving process. In other words, each of the components of creativity is activated through creative thinking techniques, from paradigm preserving to paradigm breaking, improving mental fluidity; This means that the fluidity of the designer's mind leads to an increase in the speed of action and his mental strength in generating new ideas in the creative architectural problem-solving process. Once the mind expansion improves, it enhances the designer's ability to add details to his ideas in the creative architectural problem-solving process. Improving mental initiative leads to the improvement of the designer's ability for generating new and unusual ideas in the creative architectural problem-solving process. Improving mental flexibility leads to

increasing variety and improving the ability of the designer's mental maneuver to perceive and produce new ideas in the creative architectural problem-solving process, the result of which will be then revealed in the design product in three areas of physical, function, and semantic (**Figure**. 3).

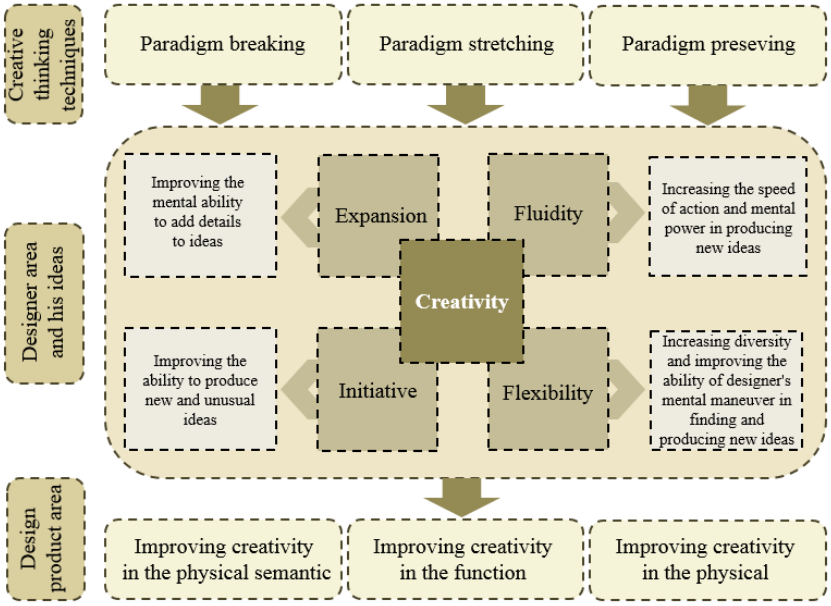

Figure. 3: The process of improving creativity in the designer, his ideas, and the designed product

Furthermore, based on the findings on the effectiveness of creative thinking techniques on the improvement of creativity in the designer and his ideas and the product designed by him, the levels of creativity can be depicted in the form of a continuum from the desire to the paradigm preserving to the paradigm breaking. The findings showed that, in the use of creative thinking techniques, the more we move from paradigm-preserving techniques to paradigm-breaking techniques, the more the level of creativity will increase. Paradigm-breaking techniques can be explained at a very high level of creativity, while paradigm stretching techniques can be explained at a high level of creativity, and paradigm-preserving techniques can be explained at a medium level of creativity (**Figure**. 4).

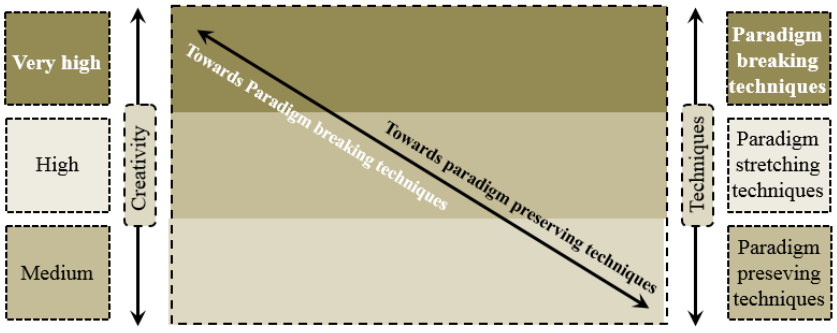

Figure. 4: Continuum of creative thinking techniques from the paradigm preserving to the paradigm breaking and its results

It should be noted that creativity stimulation techniques are different from the process of assimilation, implying teaching a different set of strategies to everyone. These techniques cultivate creativity to help people learn to be creative in their own way.

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