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Construction and Normalization of the Scale of Creativity in Architectural Design

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ABSTRACT: The ultimate goal of architectural studios is creative design. To achieve this goal, evaluating creativity in architecture education is considered as one of the important pillars of education. Due to the need for evaluation, the purpose of this study is to construct a test for measuring design creativity based on Torrance's components of creativity in architecture so that it can be used in design education. Therefore, this study seeks to create a measurable criterion for the components of Torrance using the innovative problem-solving method of Triz to evaluate creativity. The present study is descriptive-correlational. The research sample includes 32 architecture students selected by the available sampling method. Test validity is confirmed through confirmatory factor analysis (($\chi2$ / df = 1.68), (CFI = 0.97), (GFI = 0.98), (AGFI = 0.97) and (0.08 = RMSEA)), which shows that the model fits the data. The correlation between the creativity scale in architecture and Torrance creativity and CREE is significant, indicating the scale's convergent validity. In addition, through the split-half technique and in the method of random pairs, the. coefficient of validity for the component of flexibility, originality, expansion, and the total scale is equal to 0.90, 0.80, 0.75, and 0.91, respectively. Due to the good psychometrics of this tool reported in the research, it is a valid tool that can measure the increase in creativity components in architectural design and can be used in architectural studios and educational and psychological research

Keywords: *Scale of creativity, Triz, Torrance, Architecture education.*

INTRODUCTION

Designing is the main aspect of architectural education in most educational centers worldwide. The ultimate goal of architectural studios is to promote creativity for design (Mahmoudi, 1998; Nadimi, 2016; Mahdavi Nejad, 2005). Creativity assessment is one of the most important factors in its promotion which needs to be constantly evaluated in educational processes (Casakin & Kritler, 2006; Demirkan & Afacan, 2012; Chiu & Salustri, 2010; Casakin et al., 2019; Koronis et al., 2018; Xiong et al., 2019; Williams et al., 2010). Therefore, creating a tool for evaluating design creativity in educational processes seems necessary.

There exist numerous tools for creativity assessment in various research fields; one of the most widely used tests of their kind is the Torrance Creativity Test in educational measurement, which consists of four main elements: flexibility, fluency, originality, and elaboration (O'Neil et al., 1994). Another suitable instrument to assess creativity is the Abedi Creativity Test, which was developed based on the Torrance Test of Creative Thinking (TTCT) theory, presented by O'Neil et al. in 1994 and used in various studies (Dayemi & Moghimi Barforush, 2004; Forouzanfar et al., 2018)

Torsten - Milenjer Creativity Questionnaire (CREE) is a semi-hidden creativity test used for both individuals and groups to identify the potential creativity of examinees and has been used in a large body of studies (Nasiri & Arefi, 2015; Hassanzadeh & Eimanifar, 2010).

Further review of the existing research literature shows that these tests are primarily designed to measure young children's creativity at an individual level. In most of these studies, a questionnaire is employed to measure individual creativity and the metacognitive components of Torrance creativity; however, a limited number of studies have emphasized the evaluation of the product, process, and place (Demirkan & Afacan, 2012; Chulvi et al2012 ,.; Kalantari et al2020 ,.; Watters, 2017; Betz, 2009).

For example, the evaluation tools of this kind include the Creative Thinking- Production, and Drawing- Test of Urban (2004) and the Amabil Consensus Assessment Technique (CAT) (Watters, 2017). Also, the research of Betz (2009) is focused on evaluating design creativity as a creative product in architecture education. They showed that by reviewing and analyzing

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*Corresponding Author Email: *a.nourtaghani@gu.ac.ir* projects by professors and students in architecture studios, they could be comparatively analyzed, critiqued, and evaluated; Comparison between professors' scores and students' collective rankings shows a strong correlation between identifying the most and least creative projects, but differences in previous experience between professors and students did not play a role in the evaluation results.

However, despite the multiplicity of research studies measuring product creativity in most of these research studies, unlike measuring individual creativity, which was quantitative methods, is often qualitative or person-centered score criteria; accurate indicators for measuring creativity have not been reported. Since the challenge of teaching architecture is to nurture students in creative design (Mahmoudi, 2002; Sobhiyah et al., 2008) and design evaluation is considered as one of the main dimensions of creativity education, having a specific tool to evaluate the design creativity of students in architecture studios is a serious necessity.

Creative problem solving is defined as a problem that contains at least one contradiction, and a creative solution is the one that can resolve such a contradiction (Farid et al., 2008; Altshuller, 2002). Since architectural design is considered as a kind of creative problem solving (Nadimi, 2016; Daneshgar Moghadam, 2009), the architectural design or the product of creativity can resolve these contradictions. On the other hand, TRIZ is one of the methods that can systematically examine the process of creative problem solving and promote creativity (Isfahani & Bahrampour, 2017; Fiorineschi et al., 2018; Keong et al., 2017).

A large body of research claimed that Triz education could promote metacognitive components of creativity in students (fluency, flexibility, originality, and elaboration). Students who are taught TRIZ can come up with original and innovative solutions. Additionally, they can develop a wider range of ideas (Isfahani & Bahrampour, 2017; Jahan et al., 2014; Yaghoubi & Jahan, 2015).

Consequently, we redefined Torrance's metacognitive components to develop a tool for measuring creativity in architectural design. We used TRIZ key tools such as 40 innovative principles, 39 technical parameters, and a contradiction table to develop a reliable scale to assess creativity in architectural design studios.

Therefore, this research aims to design a measurement tool based on TRIZ problem solving and Torrance creativity components that can assess design creativity as a creative product in architectural studios and evaluate its validity and reliability. This research will address creativity assessment and allow instructors to use this scale to measure creativity in architectural design studios. The following questions are posed to fulfill the research aims:

Is this measurement tool valid enough to assess creativity in architectural design?

Is this measurement tool reliable enough to assess creativity in architectural design?

Theoretical Framework

Tests are an important part of cognitive measurements and assessments, which are the indicators of the main part of the tests. In this regard, various indicators have been presented to evaluate the promotion of creativity in design. In a study, Aderonmu et al. (2019) stated that innovation is one of the main components in evaluating creativity. In another study, Xiong et al. (2019) developed the GT-DANO-MV model for quantitative and qualitative evaluation to systematically improve the creativity of design students, stating that this model allows professionals to make sound judgments. Evaluation is an important part of architectural practice, and the purpose of the evaluation is to analyze the latent features and novelty of the product. Hargrove (2012) states that design is the heart of the curriculum in all architectural schools. More attention is paid to its aesthetic importance in architectural design than its cognitive nature. The evaluation criterion is the product instead of the process or skill used, so cognitive skills are not generally examined, and learning opportunities are delayed or eliminated. In another study, Kasakin & Kreitler (2006) state that the evaluation of design creativity is one of the most important aspects of curricula in design and architecture schools. The findings of this study showed that the overall evaluation of design creativity is mainly related to design innovation

Many studies have evaluated the product. For example, a study by Chiu & Salustri (2010), referring to the multidimensionality of creativity, addresses how to measure creativity and considers other researchers' opinions on creativity (Torrance, 1998; Montigny & Smitherson, 2009). He points out that one of the main factors in design creativity is its surprisingness. Others argue that useful design should be appropriate, practical, and valuable (Amabile, 1983; Akin & Akin, 1998; De Bono, 1995). Other researchers consider detail and delicacy as criteria for evaluating creativity (Besemer & Treffinger, 1981; Torrance, 1998). Some cite sincerity and usefulness as a condition of a creative product (Amabile, 1983; Akin & Akin, 1998). Moreover, some introduce usefulness for engineering creativity (Ullman, 2003; Beitz & Pahl, 1996). In a study by Ullman (2003), he showed that creative ideas should be more than a good idea and solve a problem. De Bono (1992) emphasizes that creative ideas include fundamental logic, value, and innovation. This study stimulated creativity with techniques such as Triz, random stimuli, and brainstorming. After peer-to-peer evaluation, it was found that there was a high correlation between innovation and usefulness in human judgments by a peer (As cited in Chiu & Salstori, 2010). Horn & Salvendy (2006,2009) expressed the product creativity evaluation model in the form of 6 factors: clarity, feeling, centrality, importance, desire, and innovation, the most important of which are importance and novelty factors (As cited in Demirkan & Afacan, 2012, 264). Torrance (1965) also considers creativity a combination of four main factors. The fluidity factor is related to the number of answers to a problem; flexibility is the ability to think in different ways to solve a new problem; originality is the ability to think unconventionally and uncommonly. The originality of the initiative is based on providing unusual, surprising, and shrewd answers to problems, and the final factor is the expansion of the ability to pay attention to detail while performing an activity.

A review of the research showed that the factors presented by Torrance are more comprehensive than other indicators. In this research, these four creativity factors are the criteria for making tools. As stated, the creative solution is to respond to the contradictions of the creative problem. Since the theory of innovative problem solving (Triz) was very useful in this field and is very inclusive, the measurement of each of Torrance's indicators has been done based on this theory, which is stated in the following.

TRIZ: TRIZ is a Russian acronym for "Teoriya Resheniya Izobrototelskikh Zadatch," also known as TIPS when translated into English, meaning "Theory of Inventive Problem Solving." G. Alsthuller has developed TRIZ to help designers be more creative (Mansourian, 2007). Altshuller et al.(1996), from their research on over 40,000 inventive patents, realized that the inventions and innovations are subject to certain principles and patterns, which means that they can be repeated and used for future problem-solving. He found that only 39 features either improve or degrade. As a result, he used the principles for 1201 contradictions and named them "contradiction." He concluded that only 40 inventive principles were used to resolve these contradictions fully (Pellet & Hey, 2011; Scheiner et al., 2014). Recent research suggests that using TRIZ showed an improvement of 70% to 300% or more in the number of creative ideas generated for solving technical problems and the speed with which innovative ideas are generated (Ardakani, 2008).

Triz's theory is based on two dimensions of the technical system and contradictions. In a technical system, anything with a function is a technical system. Each system can have several subsystems, each being a system in itself. In the dimension of contradictions, the most efficient and best solutions are obtained when an inventor can solve technical problems that have a contradiction. When and where does a contradiction occur? Contradiction occurs when we try to improve one feature or parameter, but we weaken another feature (Ilevbare et al., 2013). A technical system has several features and parameters, such as weight, shape, size, color, speed. When technical problems are solved, these parameters help to define the existing technical contradictions. The main tools of TRIZ have three components: the principles, technical parameters, and contradiction matrix. The scoring of Torrance components is based on these three components of the Triz tool.

Principles: The tools used within TRIZ to resolve technical contradictions are called principles. For example, the separation principle helps us separate a component from the technical system and change it into a large number of interconnected smaller items (Table 1)

Technical Parameters Altshuller realized that inventions and innovations are subject to certain principles and patterns. He also standardized and summarized the engineering parameters present in contradictions to a 39-entry list. Inventors are mostly used to state the problem based on at least one contradiction and then remove these contradictions by trial and error or by relying on existing knowledge or even developing a technology to solve the problem. Contradictions are usually resolved by using tools or materials that facilitate the elimination process. Moreover, this problem-solving model has been frequently used by inventors for various technical problems and indifferent research fields to eliminate contradictions through trial and error. Altshuler identified, standardized, and categorized all these challenging technical characteristics and named them "39 Technical and engineering Parameters". These parameters help define the problem systematically and identify contradictions existing between two or more parameters in technical systems. Table 2 illustrates the 39 engineering parameters.

Contradiction Matrix: The contradiction matrix comprises a list of parameters so that the system's parameter whose improvement leads to the elimination of the undesired effect (UDE) can be identified. Additionally, the corresponding parameter that is getting worse can also be identified. The improving parameters are listed in the first column and the worsening parameter in the first row (row = the parameter to be improved, column = that parameter that worsens). The table provides a list of principles that can be reviewed to resolve the contradiction in the corresponding intersection. A full version of the matrix is shown in Table 3.

Table 1: TRIZ Forty Inventive Principles (Source: Mansourian, 2007)

Principles 1 to 20		Principles 21 to 39	
1	Segmentation	21	Rushing Through
2	Extraction (Extracting, Retrieving, Removing)	22	Convert Harm Into Benefit
3	Local Quality	23	Feedback
4	Asymmetry	24	Mediator
5	Consolidation	25	Self-service
6	Universality	26	Copying
7	Nesting (Matrioshka)	27	Dispose
8	Counterweight	28	Replacement of Mechanical System
9	Prior Counteraction	29	Pneumatic or Hydraulic Constructions
10	Prior Action	30	Flexible Membranes or Thin Films
11	Cushon in Advance	31	Porous Material
12	Equipotentiality	32	Changing the Color
13	Do It in Reverse	33	Homogeneity
14	Spheroidality	34	Rejecting and Regenerating Parts
15	Dynamicity	35	Transformation of Properties

Continiue of Table 1: TRIZ Forty Inventive Principles (Source: Mansourian, 2007)

16	Partial or Excessive Action	36	Phase Transition
17	Transition Into a New Dimension	37	Thermal Expansion
18	Mechanical Vibration	38	Accelerated Oxidation
19	Periodic Action	39	Inert Environment
20	Continuity of Useful Action	40	Composite Materials

MATERIALS AND METHODS

Research Design and Participants

A total of 32 students of Architecture (20 from Gorgan Azad University & 12 from Gonbad Azad University) in their first semester of sophomore year in 2018, attending Preliminary Design course, were selected using convenience sampling procedure to participate in this descriptive correlational study.

Due to the limitations of the sample in this study, the main problem is the validity and reliability of the test as two important indicators that show the accuracy of the score obtained. These indicators are affected by the sample size. Having a representative sample is very important in making tests. The representative sample can be inferred from the indicators obtained from the validity study (factor analysis) and reliability (retest method). Although most tests use different samples, representativeness is the most important factor. It is worth highlighting that the fit indices of this study's confirmatory factor analysis model have shown that all are at the desired level, and the data fit the conceptual model. Therefore, the test is of an acceptable level of construct validity, and this number of samples seems to be sufficient to make this test.

Research Tools

Creativity in architectural design test: This test, which is based

Table 2: Technical parameters: (Source: Altshuller, 2002)

Principles 1 to 20		Principles 21 to 39	
1	Weight of mobile object1	21	Power
2	Weight of the stationary object	22	Loss of energy
3	Length of the mobile object	23	Loss of substance
4	Length of the stationary object	24	Loss of information
5	Area of the mobile object	25	Loss of time
6	Area of the stationary object	26	Amount of substance
7	The volume of the mobile object	27	Reliability
8	The volume of the mobile object	28	Accuracy of measurement
9	Speed	29	Accuracy of manufacturing
10	Force	30	Harmful factors acting on an object from outside
11	Tension / Pressure	31	Harmful factors developed by an object
12	Shape	32	Manufacturability
13	Stability of composition	33	Convenience of use
14	Strength	34	Repairability
15	Time of action of moving object	35	Adaptability
16	Time of action of the stationary object	36	Complexity of device
17	Temperature	37	Complexity of device
18	rightness	38	Level of automation
19	Energy Spent by a moving object	39	Capacity / Productivity
20	Energy Spent by a stationary object		

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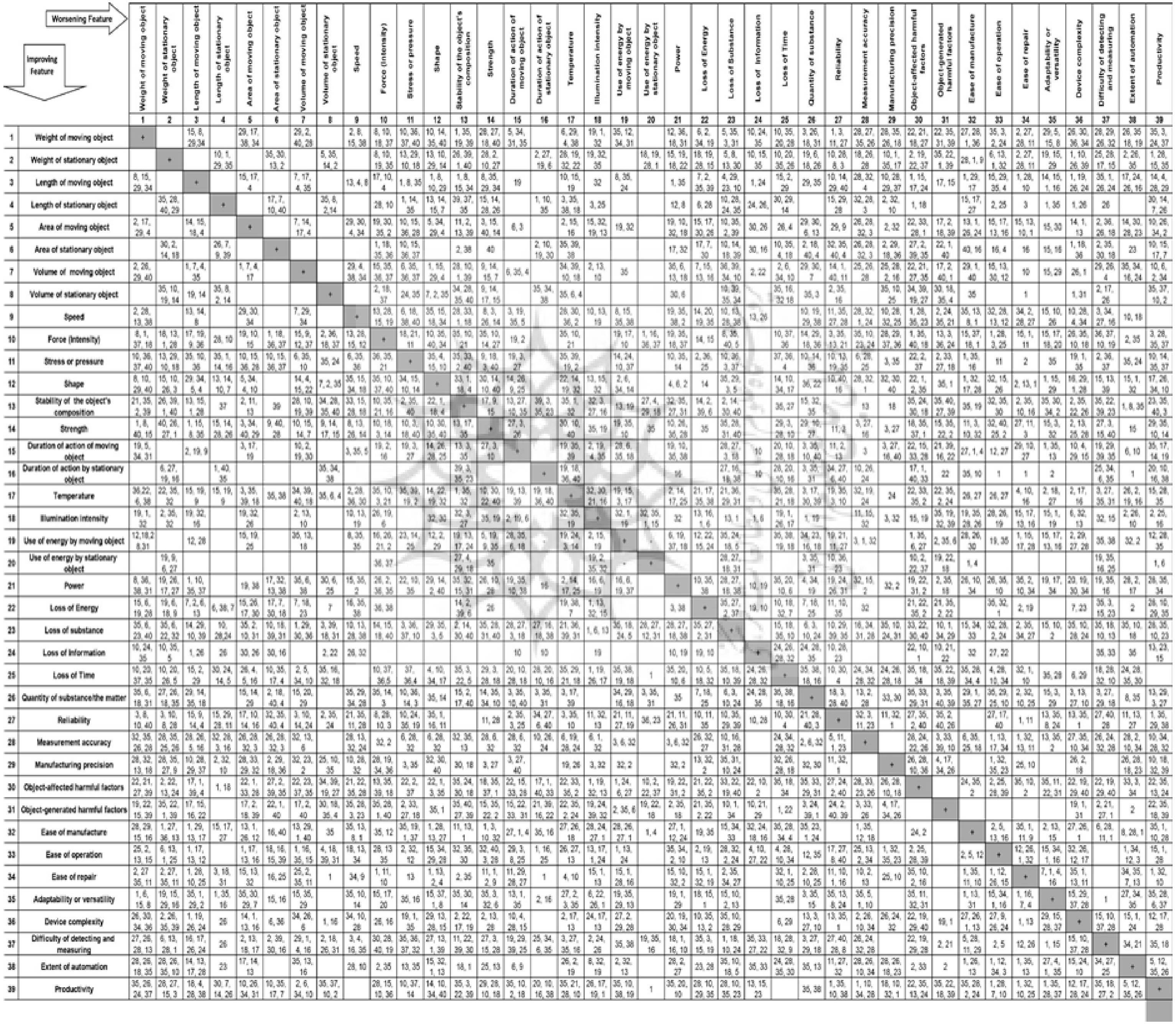
Table 3: Contradiction Matrix (Source: Altshuller, 2002)



	Worsening Feature Improving Feature	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object	Speed	Force (Intensity)	Stress or pressure	Shape	Stability of the object's composition	Strength	Duration of action of moving object	Duration of action of stationary object	Temperature	Illumination intensity	Use of energy by moving object	Use of energy by stationary object	Power	Loss of Energy	Loss of Substance	Loss of Information	Loss of Time	Quantity of substance	Reliability	Measurement accuracy	Manufacturing precision	Object-affected harmful factors	Object-generated harmful factors	Ease of manufacture	Ease of operation	Ease of repair	Adaptability or versatility	Device complexity	Difficulty of detecting and measuring	Extent of automation	Productivity
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
1	Weight of moving object	+		15, 8, 29, 34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35		6, 29, 4, 38	19, 1, 32	35, 12, 34, 31		12, 36, 18, 31	6, 2, 34, 19	5, 35, 3, 31	10, 24, 35	10, 35, 20, 28	3, 26, 18, 31	1, 3, 11, 27	28, 27, 35, 26	28, 35, 26, 18	22, 21, 18, 27	22, 35, 31, 39	27, 28, 1, 36	35, 3, 2, 24	2, 27, 28, 11	29, 5, 15, 8	26, 30, 36, 34	28, 29, 26, 32	26, 35 18, 19	35, 3, 24, 37
2	Weight of stationary object		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27		2, 27, 19, 6	28, 19, 32, 22	19, 32, 35		18, 19, 28, 1	15, 19, 18, 22	18, 19, 28, 15	5, 8, 13, 30	10, 15, 35	10, 20, 35, 26	19, 6, 18, 26	10, 28, 8, 3	18, 26, 28	10, 1, 35, 17	2, 19, 22, 37	35, 22, 1, 39	28, 1, 9	6, 13, 1, 32	2, 27, 28, 11	19, 15, 29	1, 10, 26, 39	25, 28, 17, 15	2, 26, 35	1, 28, 15, 35
3	Length of moving object	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19		10, 15, 19	32	8, 35, 24		1, 35	7, 2, 35, 39	4, 29, 23, 10	1, 24	15, 2, 29	29, 35	10, 14, 29, 40	28, 32, 4	10, 28, 29, 37	1, 15, 17, 24	17, 15	1, 29, 17	15, 29, 35, 4	1, 28, 10	14, 15, 1, 16	1, 19, 26, 24	35, 1, 26, 24	17, 24, 26, 16	14, 4, 28, 29
4	Length of stationary object		35, 28, 40, 29		+		17, 7, 10, 40		35, 8, 2, 14		28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26		1, 10, 35	3, 35, 38, 18	3, 25			12, 8	6, 28	10, 28, 24, 35	24, 26,	30, 29, 14		15, 29, 28	32, 28, 3	2, 32, 10	1, 18		15, 17, 27	2, 25	3	1, 35	1, 26	26		30, 14, 7, 26
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4		+		7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3		2, 15, 16	15, 32, 19, 13	19, 32		19, 10, 32, 18	15, 17, 30, 26	10, 35, 2, 39	30, 26	26, 4	29, 30, 6, 13	29, 9	26, 28, 32, 3	2, 32	22, 33, 28, 1	17, 2, 18, 39	13, 1, 26, 24	15, 17, 13, 16	15, 13, 10, 1	15, 30	14, 1, 13	2, 36, 26, 18	14, 30, 28, 23	10, 26, 34, 2
6	Area of stationary object		30, 2, 14, 18		26, 7, 9, 39		+				1, 18, 35, 36	10, 15, 36, 37		2, 38	40		2, 10, 19, 30	35, 39, 38				17, 32	17, 7, 30	10, 14, 18, 39	30, 16	10, 35, 4, 18	2, 18, 40, 4	32, 35, 40, 4	26, 28, 32, 3	2, 29, 18, 36	27, 2, 39, 35	22, 1, 40	40, 16	16, 4	16	15, 16	1, 18, 36	2, 35, 30, 18	23	10, 15, 17, 7
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17		+		29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4		34, 39, 10, 18	2, 13, 10	35		35, 6, 13, 18	7, 15, 13, 16	36, 39, 34, 10	2, 22	2, 6, 34, 10	29, 30, 7	14, 1, 40, 11	25, 26, 28	25, 28, 2, 16	22, 21, 27, 35	17, 2, 40, 1	29, 1, 40	15, 13, 30, 12	10	15, 29	26, 1	29, 26, 4	35, 34, 16, 24	10, 6, 2, 34
8	Volume of stationary object		35, 10, 19, 14	19, 14	35, 8, 2, 14				+		2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15		35, 34, 38	35, 6, 4				30, 6		10, 39, 35, 34		35, 16, 32 18	35, 3	2, 35, 16		35, 10, 25	34, 39, 19, 27	30, 18, 35, 4	35		1		1, 31	2, 17, 26		35, 37, 10, 2
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34		+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5		28, 30, 36, 2	10, 13, 19	8, 15, 35, 38		19, 35, 38, 2	14, 20, 19, 35	10, 13, 28, 38	13, 26		10, 19, 29, 38	11, 35, 27, 28	28, 32, 1, 24	10, 28, 32, 25	1, 28, 35, 23	2, 24, 35, 21	35, 13, 8, 1	32, 28, 13, 12	34, 2, 28, 27	15, 10, 26	10, 28, 4, 34	3, 34, 27, 16	10, 18	
10	Force (Intensity)	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27	19, 2		35, 10, 21		19, 17, 10	1, 16, 36, 37	19, 35, 18, 37	14, 15	8, 35, 40, 5		10, 37, 36	14, 29, 18, 36	3, 35, 13, 21	35, 10, 23, 24	28, 29, 37, 36	1, 35, 40, 18	13, 3, 36, 24	15, 37, 18, 1	1, 28, 3, 25	15, 1, 11	15, 17, 18, 20	26, 35, 10, 18	36, 37, 10, 19	2, 35	3, 28, 35, 37
11	Stress or pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 28	10, 15, 36, 37	6, 35, 10	35, 24	6, 35, 36	36, 35, 21	+	35, 4, 15, 10	35, 33, 2, 40	9, 18, 3, 40	19, 3, 27		35, 39, 19, 2		14, 24, 10, 37		10, 35, 14	2, 36, 25	10, 36, 3, 37		37, 36, 4	10, 14, 36	10, 13, 19, 35	6, 28, 25	3, 35	22, 2, 37	2, 33, 27, 18	1, 35, 16	11	2	35	19, 1, 35	2, 36, 37	35, 24	10, 14, 35, 37
12	Shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14	+	33, 1, 18, 4	30, 14, 10, 40	14, 26, 9, 25		22, 14, 19, 32	13, 15, 32	2, 6, 34, 14		4, 6, 2	14	35, 29, 3, 5		14, 10, 34, 17	36, 22	10, 40, 16	28, 32, 1	32, 30, 40	22, 1, 2, 35	35, 1	1, 32, 17, 28	32, 15, 26	2, 13, 1	1, 15, 29	16, 29, 1, 28	15, 13, 39	15, 1, 32	17, 26, 34, 10
13	Stability of the object's composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4	+	17, 9, 15	13, 27, 10, 35	39, 3, 35, 23	35, 1, 32	32, 3, 27, 16	13, 19	27, 4, 29, 18	32, 35, 27, 31	14, 2, 39, 6	2, 14, 30, 40		35, 27	15, 32, 35		13	18	35, 24, 30, 18	35, 40, 27, 39	35, 19	32, 35, 30	2, 35, 10, 16	35, 30, 34, 2	2, 35, 22, 26	35, 22, 39, 23	1, 8, 35	23, 35, 40, 3
14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35	+	27, 3, 26		30, 10, 40	35, 19	19, 35, 10	35	10, 26, 35, 28	35	35, 28, 31, 40		29, 3, 28, 10	29, 10, 27	11, 3	3, 27, 16	3, 27	18, 35, 37, 1	15, 35, 22, 2	11, 3, 10, 32	32, 40, 25, 2	27, 11, 3	15, 3, 32	2, 13, 25, 28	27, 3, 15, 40	15	29, 35, 10, 14
15	Duration of action of moving object	19, 5, 34, 31		2, 19, 9		3, 17, 19		10, 2, 19, 30		3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10	+		19, 35, 39	2, 19, 4, 35	28, 6, 35, 18		19, 10, 35, 38		28, 27, 3, 18	10	20, 10, 28, 18	3, 35, 10, 40	11, 2, 13	3	3, 27, 16, 40	22, 15, 33, 28	21, 39, 16, 22	27, 1, 4	12, 27	29, 10, 27	1, 35, 13	10, 4, 29, 15	19, 29, 39, 35	6, 10	35, 17, 14, 19
16	Duration of action by stationary object		6, 27, 19, 16		1, 40, 35				35, 34, 38					39, 3, 35, 23			+	19, 18, 36, 40				16		27, 16, 18, 38	10	28, 20, 10, 16	3, 35, 31	34, 27, 6, 40	10, 26, 24		17, 1, 40, 33	22	35, 10	1	1	2		25, 34, 6, 35	1	20, 10, 16, 38
17	Temperature	36, 22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4	2, 28, 36, 30	35, 10, 3, 21	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40	+	32, 30, 21, 16	19, 15, 3, 17		2, 14, 17, 25	21, 17, 35, 38	21, 36, 29, 31		35, 28, 21, 18	3, 17, 30, 39	19, 35, 3, 10	32, 19, 24	24	22, 33, 35, 2	22, 35, 2, 24	26, 27	26, 27	4, 10, 16	2, 18, 27	2, 17, 16	3, 27, 35, 31	26, 2, 19, 16	15, 28, 35
18	Illumination intensity	19, 1, 32	2, 35, 32	19, 32, 16		19, 32, 26		2, 13, 10		10, 13, 19	26, 19, 6		32, 30	32, 3, 27	35, 19	2, 19, 6		32, 35, 19	+	32, 1, 19	32, 35, 1, 15	32	13, 16, 1, 6	13, 1	1, 6	19, 1, 26, 17	1, 19		11, 15, 32	3, 32	15, 19	35, 19, 32, 39	19, 35, 28, 26	28, 26, 19	15, 17, 13, 16	15, 1, 19	6, 32, 13	32, 15	2, 26, 10	2, 25, 16
19	Use of energy by moving object	12, 18, 28, 31		12, 28		15, 19, 25		35, 13, 18		8, 35, 35	16, 26, 21, 2	23, 14, 25	12, 2, 29	19, 13, 17, 24	5, 19, 9, 35	28, 35, 6, 18		19, 24, 3, 14	2, 15, 19	+		6, 19, 37, 18	12, 22, 15, 24	35, 24, 18, 5		35, 38, 19, 18	34, 23, 16, 18	19, 21, 11, 27	3, 1, 32		1, 35, 6, 27	2, 35, 6	28, 26, 30	19, 35	1, 15, 17, 28	15, 17, 13, 16	2, 29, 27, 28	35, 38	32, 2	12, 28, 35
20	Use of energy by stationary object		19, 9, 6, 27								36, 37			27, 4, 29, 18	35				19, 2, 35, 32		+			28, 27, 18, 31			3, 35, 31	10, 36, 23			10, 2, 22, 37	19, 22, 18	1, 4					19, 35, 16, 25		1, 6
21	Power	8, 36, 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25	15, 35, 2	26, 2, 36, 35	22, 10, 35	29, 14, 2, 40	35, 32, 15, 31	26, 10, 28	19, 35, 10, 38	16	2, 14, 17, 25	16, 6, 19	16, 6, 19, 37		+	10, 35, 38	28, 27, 18, 38	10, 19	35, 20, 10, 6	4, 34, 19	19, 24, 26, 31	32, 15, 2	32, 2	19, 22, 31, 2	2, 35, 18	26, 10, 34	26, 35, 10	35, 2, 10, 34	19, 17, 34	20, 19, 30, 34	19, 35, 16	28, 2, 17	28, 35, 34
22	Loss of Energy	15, 6, 19, 28	19, 6, 18, 9	7, 2, 6, 13	6, 38, 7	15, 26, 17, 30	17, 7, 30, 18	7, 18, 23	7	16, 35, 38	36, 38			14, 2, 39, 6	26			19, 38, 7	1, 13, 32, 15			3, 38	+	35, 27, 2, 37	19, 10	10, 18, 32, 7	7, 18, 25	11, 10, 35	32		21, 22, 35, 2	21, 35, 2, 22		35, 32, 1	2, 19		7, 23	35, 3, 15, 23	2	28, 10, 29, 35
23	Loss of substance	35, 6, 23, 40	35, 6, 22, 32	14, 29, 10, 39	10, 28, 24	35, 2, 10, 31	10, 18, 39, 31	1, 29, 30, 36	3, 39, 18, 31	10, 13, 28, 38	14, 15, 18, 40	3, 36, 37, 10	29, 35, 3, 5	2, 14, 30, 40	35, 28, 31, 40	28, 27, 3, 18	27, 16, 18, 38	21, 36, 39, 31	1, 6, 13	35, 18, 24, 5	28, 27, 12, 31	28, 27, 18, 38	35, 27, 2, 31	+		15, 18, 35, 10	6, 3, 10, 24	10, 29, 39, 35	16, 34, 31, 28	35, 10, 24, 31	33, 22, 30, 40	10, 1, 34, 29	15, 34, 33	32, 28, 2, 24	2, 35, 34, 27	15, 10, 2	35, 10, 28, 24	35, 18, 10, 13	35, 10, 18	28, 35, 10, 23
24	Loss of Information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22	26, 32						10	10		19			10, 19	19, 10		+	24, 26, 28, 32	24, 28, 35	10, 28, 23			22, 10, 1	10, 21, 22	32	27, 22				35, 33	35	13, 23, 15
25	Loss of Time	10, 20, 37, 35	10, 20, 26, 5	15, 2, 29	30, 24, 14, 5	26, 4, 5, 16	10, 35, 17, 4	2, 5, 34, 10	35, 16, 32, 18		10, 37, 36, 5	37, 36, 4	4, 10, 34, 17	35, 3, 22, 5	29, 3, 28, 18	20, 10, 28, 18	28, 20, 10, 16	35, 29, 21, 18	1, 19, 26, 17	35, 38, 19, 18	1	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32	+	35, 38, 18, 16	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34	35, 22, 18, 39	35, 28, 34, 4	4, 28, 10, 34	32, 1, 10	35, 28	6, 29	18, 28, 32, 10	24, 28, 35, 30	
26	Quantity of substance/the matter	35, 6, 18, 31	27, 26, 18, 35	29, 14, 35, 18		15, 14, 29	2, 18, 40, 4	15, 20, 29		35, 29, 34, 28	35, 14, 3	10, 36, 14, 3	35, 14	15, 2, 17, 40	14, 35, 34, 10	3, 35, 10, 40	3, 35, 31	3, 17, 39		34, 29, 16, 18	3, 35, 31	35	7, 18, 25	6, 3, 10, 24	24, 28, 35	35, 38, 18, 16	+	18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 29, 31	3, 35, 40, 39	29, 1, 35, 27	35, 29, 25, 10	2, 32, 10, 25	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35	13, 29, 3, 27
27	Reliability	3, 8, 10, 40	3, 10, 8, 28	15, 9, 14, 4	15, 29, 28, 11	17, 10, 14, 16	32, 35, 40, 4	3, 10, 14, 24	2, 35, 24	21, 35, 11, 28	8, 28, 10, 3	10, 24, 35, 19	35, 1, 16, 11		11, 28	2, 35, 3, 25	34, 27, 6, 40	3, 35, 10	11, 32, 13	21, 11, 27, 19	36, 23	21, 11, 26, 31	10, 11, 35	10, 35, 29, 39	10, 28	10, 30, 4	21, 28, 40, 3	+	32, 3, 11, 23	11, 32, 1	27, 35, 2, 40	35, 2, 40, 26		27, 17, 40	1, 11	13, 35, 8, 24	13, 35, 1	27, 40, 28	11, 13, 27	1, 35, 29, 38
28	Measurement accuracy	32, 35, 26, 28	28, 35, 25, 26	28, 26, 5, 16	32, 28, 3, 16	26, 28, 32, 3	26, 28, 32, 3	32, 13, 6		28, 13, 32, 24	32, 2	6, 28, 32	6, 28, 32	32, 35, 13	28, 6, 32	28, 6, 32	10, 26, 24	6, 19, 28, 24	6, 1, 32	3, 6, 32		3, 6, 32	26, 32, 27	10, 16, 31, 28		24, 34, 28, 32	2, 6, 32	5, 11, 1, 23	+		28, 24, 22, 26	3, 33, 39, 10	6, 35, 25, 18	1, 13, 17, 34	1, 32, 13, 11	13, 35, 2	27, 35, 10, 34	26, 24, 32, 28	28, 2, 10, 34	10, 34, 28, 32
29	Manufacturing precision	28, 32, 13, 18	28, 35, 27, 9	10, 28, 29, 37	2, 32, 10	28, 33, 29, 32	2, 29, 18, 36	32, 23, 2	25, 10, 35	10, 28, 32	28, 19, 34, 36	3, 35	32, 30, 40	30, 18	3, 27	3, 27, 40		19, 26	3, 32	32, 2		32, 2	13, 32, 2	35, 31, 10, 24		32, 26, 28, 18	32, 30	11, 32, 1		+	26, 28, 10, 36	4, 17, 34, 26		1, 32, 35, 23	25, 10		26, 2, 18		26, 28, 18, 23	10, 18, 32, 39
30	Object-affected harmful factors	22, 21, 27, 39	2, 22, 13, 24	17, 1, 39, 4	1, 18	22, 1, 33, 28	27, 2, 39, 35	22, 23, 37, 35	34, 39, 19, 27	21, 22, 35, 28	13, 35, 39, 18	22, 2, 37	22, 1, 3, 35	35, 24, 30, 18	18, 35, 37, 1	22, 15, 33, 28	17, 1, 40, 33	22, 33, 35, 2	1, 19, 32, 13	1, 24, 6, 27	10, 2, 22, 37	19, 22, 31, 2	21, 22, 35, 2	33, 22, 19, 40	22, 10, 2	35, 18, 34	35, 33, 29, 31	27, 24, 2, 40	28, 33, 23, 26	26, 28, 10, 18	+		24, 35, 2	2, 25, 28, 39	35, 10, 2	35, 11, 22, 31	22, 19, 29, 40	22, 19, 29, 40	33, 3, 34	22, 35, 13, 24
31	Object-generated harmful factors	19, 22, 15, 39	35, 22, 1, 39	17, 15, 16, 22		17, 2, 18, 39	22, 1, 40	17, 2, 40	30, 18, 35, 4	35, 28, 3, 23	35, 28, 1, 40	2, 33, 27, 18	35, 1	35, 40, 27, 39	15, 35, 22, 2	15, 22, 33, 31	21, 39, 16, 22	22, 35, 2, 24	19, 24, 39, 32	2, 35, 6	19, 22, 18	2, 35, 18	21, 35, 2, 22	10, 1, 34	10, 21, 29	1, 22	3, 24, 39, 1	24, 2, 40, 39	3, 33, 26	4, 17, 34, 26		+					19, 1, 31	2, 21, 27, 1	2	22, 35, 18, 39
32	Ease of manufacture	28, 29, 15, 16	1, 27, 36, 13	1, 29, 13, 17	15, 17, 27	13, 1, 26, 12	16, 40	13, 29, 1, 40	35	35, 13, 8, 1	35, 12	35, 19, 1, 37	1, 28, 13, 27	11, 13, 1	1, 3, 10, 32	27, 1, 4	35, 16	27, 26, 18	28, 24, 27, 1	28, 26, 27, 1	1, 4	27, 1, 12, 24	19, 35	15, 34, 33	32, 24, 18, 16	35, 28, 34, 4	35, 23, 1, 24		1, 35, 12, 18		24, 2		+	2, 5, 13, 16	35, 1, 11, 9	2, 13, 15	27, 26, 1	6, 28, 11, 1	8, 28, 1	35, 1, 10, 28
33	Ease of operation	25, 2, 13, 15	6, 13, 1, 25	1, 17, 13, 12		1, 17, 13, 16	18, 16, 15, 39	1, 16, 35, 15	4, 18, 39, 31	18, 13, 34	28, 13 35	2, 32, 12	15, 34, 29, 28	32, 35, 30	32, 40, 3, 28	29, 3, 8, 25	1, 16, 25	26, 27, 13	13, 17, 1, 24	1, 13, 24		35, 34, 2, 10	2, 19, 13	28, 32, 2, 24	4, 10, 27, 22	4, 28, 10, 34	12, 35	17, 27, 8, 40	25, 13, 2, 34	1, 32, 35, 23	2, 25, 28, 39		2, 5, 12	+	12, 26, 1, 32	15, 34, 1, 16	32, 26, 12, 17		1, 34, 12, 3	15, 1, 28
34	Ease of repair	2, 27 35, 11	2, 27, 35, 11	1, 28, 10, 25	3, 18, 31	15, 13, 32	16, 25	25, 2, 35, 11	1	34, 9	1, 11, 10	13	1, 13, 2, 4	2, 35	11, 1, 2, 9	11, 29, 28, 27	1	4, 10	15, 1, 13	15, 1, 28, 16		15, 10, 32, 2	15, 1, 32, 19	2, 35, 34, 27		32, 1, 10, 25	2, 28, 10, 25	11, 10, 1, 16	10, 2, 13	25, 10	35, 10, 2, 16		1, 35, 11, 10	1, 12, 26, 15	+	7, 1, 4, 16	35, 1, 13, 11		34, 35, 7, 13	1, 32, 10
35	Adaptability or versatility	1, 6, 15, 8	19, 15, 29, 16	35, 1, 29, 2	1, 35, 16	35, 30, 29, 7	15, 16	15, 35, 29		35, 10, 14	15, 17, 20	35, 16	15, 37, 1, 8	35, 30, 14	35, 3, 32, 6	13, 1, 35	2, 16	27, 2, 3, 35	6, 22, 26, 1	19, 35, 29, 13		19, 1, 29	18, 15, 1	15, 10, 2, 13		35, 28	3, 35, 15	35, 13, 8, 24	35, 5, 1, 10		35, 11, 32, 31		1, 13, 31	15, 34, 1, 16	1, 16, 7, 4	+	15, 29, 37, 28	1	27, 34, 35	35, 28, 6, 37
36	Device complexity	26, 30, 34, 36	2, 26, 35, 39	1, 19, 26, 24	26	14, 1, 13, 16	6, 36	34, 26, 6	1, 16	34, 10, 28	26, 16	19, 1, 35	29, 13, 28, 15	2, 22, 17, 19	2, 13, 28	10, 4, 28, 15		2, 17, 13	24, 17, 13	27, 2, 29, 28		20, 19, 30, 34	10, 35, 13, 2	35, 10, 28, 29		6, 29	13, 3, 27, 10	13, 35, 1	2, 26, 10, 34	26, 24, 32	22, 19, 29, 40	19, 1	27, 26, 1, 13	27, 9, 26, 24	1, 13	29, 15, 28, 37	+	15, 10, 37, 28	15, 1, 24	12, 17, 28
37	Difficulty of detecting and measuring	27, 26, 28, 13	6, 13, 28, 1	16, 17, 26, 24	26	2, 13, 18, 17	2, 39, 30, 16	29, 1, 4, 16	2, 18, 26, 31	3, 4, 16, 35	30, 28, 40, 19	35, 36, 37, 32	27, 13, 1, 39	11, 22, 39, 30	27, 3, 15, 28	19, 29, 39, 25	25, 34, 6, 35	3, 27, 35, 16	2, 24, 26	35, 38	19, 35, 16	18, 1, 16, 10	35, 3, 15, 19	1, 18, 10, 24	35, 33, 27, 22	18, 28, 32, 9	3, 27, 29, 18	27, 40, 28, 8	26, 24, 32, 28		22, 19, 29, 28	2, 21	5, 28, 11, 29	2, 5	12, 26	1, 15	15, 10, 37, 28	+	34, 21	35, 18
38	Extent of automation	28, 26, 18, 35	28, 26, 35, 10	14, 13, 17, 28	23	17, 14, 13		35, 13, 16		28, 10	2, 35	13, 35	15, 32, 1, 13	18, 1	25, 13	6, 9		26, 2, 19	8, 32, 19	2, 32, 13		28, 2, 27	23, 28	35, 10, 18, 5	35, 33	24, 28, 35, 30	35, 13	11, 27, 32	28, 26, 10, 34	28, 26, 18, 23	2, 33	2	1, 26, 13	1, 12, 34, 3	1, 35, 13	27, 4, 1, 35	15, 24, 10	34, 27, 25	+	5, 12, 35, 26
39	Productivity	35, 26, 24, 37	28, 27, 15, 3	18, 4, 28, 38	30, 7, 14, 26	10, 26, 34, 31	10, 35, 17, 7	2, 6, 34, 10	35, 37, 10, 2		28, 15, 10, 36	10, 37, 14	14, 10, 34, 40	35, 3, 22, 39	29, 28, 10, 18	35, 10, 2, 18	20, 10, 16, 38	35, 21, 28, 10	26, 17, 19, 1	35, 10, 38, 19	1	35, 20, 10	28, 10, 29, 35	28, 10, 35, 23	13, 15, 23		35, 38	1, 35, 10, 38	1, 10, 34, 28	18, 10, 32, 1	22, 35, 13, 24	35, 22, 18, 39	35, 28, 2, 24	1, 28, 7, 10	1, 32, 10, 25	1, 35, 28, 37	12, 17, 28, 24	35, 18, 27, 2	5, 12, 35, 26	+

on the components expressed in the field of creativity of Torrance, consists of five items (Friday book market stall, a tourist kiosk, a flower and plant exhibition, a midway prayer hall, and a children's house). It should be noted that this test had eight items that three were excluded from the study after the process of analysis (elementary school memories, fly swatter, and disposable umbrella) due to the inability to measure creativity. Also, it has not been calculated in this study due to time constraints in fluidity training. Therefore, the test includes three components of flexibility, originality, and elaboration. It is worth mentioning that the selection of topics was done to use both functional architectural topics and conceptual architectural topics. Their order was executed in a way that ranged from easier to harder exercises. In this test, all components in different items are scored in the same way, one of which is given as an example.

How to Use Triz Components to Score Flexibility, Originality, and Expansion in the Design Test

Flexibility: For the flexibility score, the algebraic sum of the technical parameters examined (39 technical parameters) and the innovative principles (40 principles) that the subject can use in this design are addressed to determine the flexibility score. For example, in designing a children's house in the park, one of the participants mentioned the following factors: 1- Strength, 2- Accuracy of construction, 3- Maintaining the integrity of the body, 4- Adaptability, 5- Ease of use, 6- Lighting, 7- Copying, 8- Leveling, 9- Changing properties, 10- Changing direction, 11- Multitasking, 12- Composites, 13- Dynamics, 14- Moving to another dimension, 15- Division, 16- A little less A little more, 17- Intermediary, 18- Flexible membrane, and 19- Color change (7 parameters out of 39 technical parameters and 12 principles out of 40 innovative principles have been used). Therefore, the flexibility score of this subject is the algebraic sum of the technical parameter and innovative principles' score, which is 19.

Originality: For the originality score, we only calculate the algebraic sum of the originality score, i.e., the principles that the subject used in the design, using the originality score table. (To determine the originality score, after examining the frequency of answers obtained by students, they were scored on a scale of 10. For example, answers between 90 and 100% of the answers were scored 1, and answers between 0 and 10% of the answers were scored 10, and similarly, scores were set for the other percentages. This method was performed separately for the originality score of all exercises. You can see an example of the originality table for a children's house in Table 4.)

For example, the participant draws a plan (Figure 1) and, according to Table 1, gets a score of +8 for observing leveling, i.e., all spaces are located on one floor (number 1), a score of +7 for change of direction, rotation of the main spaces to a radius of 17.5 degrees for more light (number 2), 8 for dynamics of curved corridor design for better guidance of clients (number 3), and 9 for intermediation, i.e., use of space and input as a communication filter (number 4). The sum of scores of the originality of this subject will be 32 (Figure 1, a).

Elaboration: to calculate the elaboration score, we pay attention to the details provided by the subject and specify them in the exercise by numbering and placing red stars. Then, we add these stars to obtain the elaboration score. We also assign a score to each of the documents provided in the project (for example, to the subject who provided a plan, two views, and two perspectives, 5 points were awarded separately from the details provided to score the details of the project documents), by which the score of the details provided determines the algebraic sum and the elaboration score. Note: For example, in the plans, one score is awarded for drawing details on doors and windows, allocation of special spaces such as lobbies, foyers, skylights, north signs, elevation codes, measurements, special furniture and in facades and sections, drawing details of doors and windows, elevation codes, plinths, the thickness of ceilings and showing special details in them, and in perspectives, similar to the previous, factors such as showing details of window sills, surface differences, recesses and protrusions, skylights, domes, porches, and any other details that make the design more obvious to the employer. The following factors are given a score of 1: A. Only one score is considered for repetitions. (For example, in a view or section that has several windows of the same size and shape, only one of the windows is given an elaboration score.) B. Color, when the main idea adds to the main answer. C- Shading in a thoughtful way. D- Thoughtful decorations.

Therefore, the elaboration score will be determined (Figure 1, b). For example, in the above plan, number 1 (entrance step), number 2 (sidestep), number 3 (entrance door), number 4 (a room representing other spaces), number 5 (partition space or entrance hall), number 6 (side space division space), number 7 (central courtyard), number 8 (retreat of classroom doors), and number 9 (hallway) is specified, each of which receives a score of 1.

Execution Method

As mentioned above, eight items were tested in this study, the first three of which were excluded due to their inability to measure creativity (these items are provided for further information only). The other five items are listed below.

Elementary School Memoirs: Using abstract practices to examine thinking styles and creativity factors of Torrance, i.e., flexibility, innovation, and elaboration; fly swatter: analyzing and finding design problems and drawing analytical problem-solving diagrams, presenting design ideas and solutions by resolving contradictions and familiarizing students with the heavy responsibility of design, and how much the design of a trivial device requires punctuation and accuracy; Disposable umbrella: Analyze and find design problems and draw analytical diagrams to solve problems, present design ideas and solutions by resolving contradictions without bringing recycled materials to class. The remaining items in the statistical analysis to construct the creativity test include the following.

1) Friday Book Market Stall: Students were asked to review and analyze issues related to the design of a space for Friday Book Market in the vicinity of Gorgan City Park and find possible design inconsistencies, offer different solutions, and finally, finally, the main solution.

2) Kiosk for tourism information: Considering the importance of tourism and attracting tourism, it is intended to ask students to study and analyze issues related to designing a space for tourism information in Golestan province located on Nahark-

Table 4: Scoring originality in the exercise of children's house in the park

No	Title	Originality score	.No	Title	Originality score
1	Preliminary action	7	15	Division	7
2	Nesting	10	16	Moving to another dimension	9
3	Dynamics	8	17	Multitasking	10
4	Changing Direction	7	18	Bending	10
5	Copying	5	19	A little less a little more	9
6	Color change	7	20	Turn loss into profit	10
7	Division	6	21	Asymmetry	10
8	Topical quality	10	22	Weight compensation	10
9	Changing properties	7	23	Making cognate	10
10	Leveling	8	24	Merge	10
11	Composites	8	25	Flexible membrane	10
12	Intermediary	9	26	Wind and hydraulic structure	10
13	Adaptation	7	27	Disposable	10
14	Changing parameter	10			

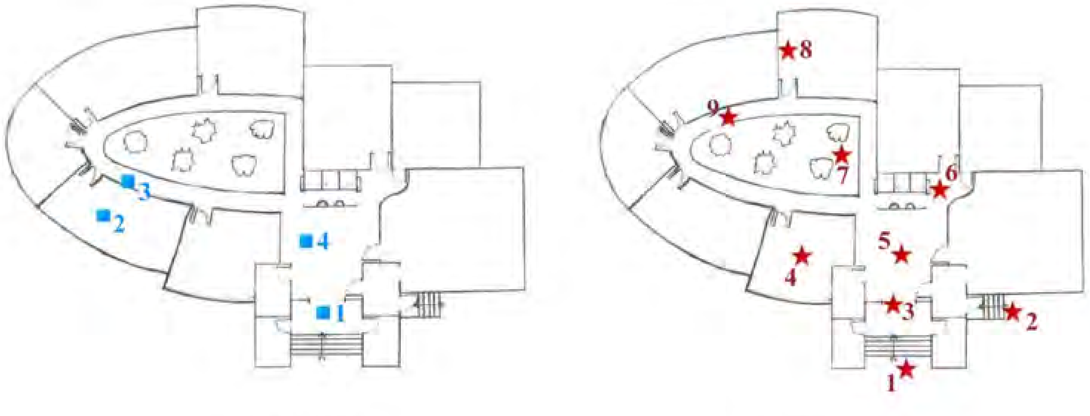
horan road and also to find possible inconsistencies in the design to provide different solutions and finally the main solution
3) Booth for flower and plant exhibition: Students, while reviewing and analyzing issues related to designing a space for flower and plant exhibition on campus, as well as finding possible inconsistencies in design, are asked to provide different solutions and finally, the main solution. It should be noted that students should pay special attention to the concepts of movement and stillness when designing.
4) Mid-way prayer hall: Students were asked to review and analyze issues related to the design of a space for the mid-way prayer hall on the Babolsar-Mahmoud Abad route and find possible discrepancies in the design to provide different solutions and, finally, the main solution.
5) Children's house in the park: While reviewing and analyzing the issues related to the design of space for the children's house in Gorgan City Park and finding possible inconsistencies in the design, students are asked to offer different solutions; finally, the main solution.
It should be noted that the test conditions were being in a quiet space and having a suitable design desk. The researchers were responsible for conducting the tests.
Figures 2 to 6 show examples of student designs. As seen in the pictures, the sheets were prepared for the students in advance. There was a part for writing design problems in these sheets, another part for writing possible contradictions in solving the problem, and apart as solutions. Before any design, students should think about these parts, complete them, and start designing. Therefore, while examining the design problems in which the design item existed, the students were able to find answers to their design problems using 39 technical parameters of TRIZ and its 40 innovative principles and the matrix of TRIZ contradictions. After finding the problems, they were adapted to the 39 technical parameters to determine which correspond to which of these problems. Then by finding the inconsistencies in the design and using the matrix of TRIZ contradictions, the use of which has been explained in the section on theoretical foundations, appropriate solutions were found (Fig. 2-6).

Method of Analysis

This study used confirmatory factor analysis and Pearson product-moment correlation coefficient to calculate convergent validity. In addition, the validity coefficient was calculated through the same correlation coefficient and Spearman-Brown correction formula. The calculations were performed by LISREL software version 8.72 and SPSS statistical package version 22.

RESULTS AND DISCUSSION

The participants of this study were 32 people, 11 of whom were boys (34.4%), and the other 21 were girls (65.6%). The mean age of all participants was 22.69, with a standard deviation of 5.67. The purpose of this study, as mentioned, was to construct a creativity test based on Torrance's theory of creativity concerning the art of design in architecture. Accordingly, in the present study, confirmatory factor analysis was used to determine the validity of the test. Convergent validity was also examined through the correlation between this test and Torrance and CREE creativity tests, which are presented below. Confirmatory factor analysis is one of the methods of measuring test validity. This statistical technique shows us whether what we define as a construct is true or not. For example, is creativity composed of flexibility, originality, and elaboration components? Whenever the conceptual model of creativity, which in this study includes the three components of flexibility, originality, and elaboration, fits with the data collected from the tool



A: Originality

B: Elaboration

Fig. 1: The how of scoring a picture item of a children's house in the park

for which it was made, it means that the construct is conceptually and operationally defined correctly. It should be noted that before testing the conceptual model, the scatter distribution of each item was examined (Table 5).

As shown in Table 5, the distribution of scores is normal in all participants, and the indices of skewness and kurtosis of the items in the components also indicate that the amount of skewness and kurtosis in the items did not exceed ±1.96, and the data distribution is normal. After examining the descriptive indicators and the distribution of items, the conceptual model of the creativity test in architecture was tested through confirmatory factor analysis. Model fit indicators indicate a good fit of the model with the data. Chi-square (χ 2) with a value of 146.31 and a degree of freedom of 87, softened chi-square ($\chi2$ / df = 1.68), comparison fit index (CFI = 0.97), good fit index (0.98 = GFI), the softened goodness-of-fit index (AGFI = 0.97) and the root mean squared error (RMSEA = 0.08) are all at the desired level; therefore, the data fits the conceptual model, and the test has construct validity.

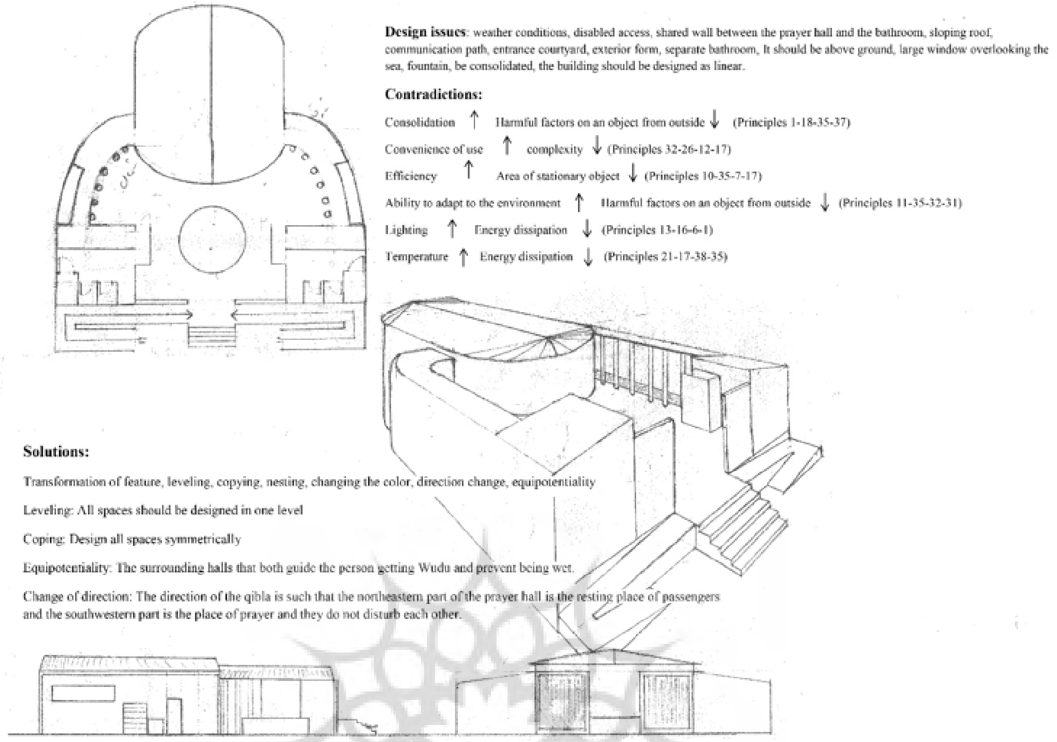
The results obtained from factor loads show flexibility, originality, and elaboration, respectively. Each component has five items as its marker. The indicators obtained from the factor load of the items in each component show how much that item can contribute to measuring the components. The results show that, in general, flexible items have higher factor loads. The first item is less important than the other items in the elaboration.

Table 5 shows the factor loads along with the error and t-value. Whenever the value of t is higher than 1.96 and less than 3, the estimated factor load is significant with a probability of 95%. Whenever this value is higher than 3, the calculated factor load is significant with a probability of 99%. Significance of factor loads means that the item can measure the desired component and can be used as a marker to measure the creativity component of creativity. The results show that all items have a value of t above 1.96, so these markers can measure the components of creativity.

The FL, OR, and EL abbreviations in Figure 7 show flexibility, originality, and expansion, respectively. Each component has five items as its indicator. The indices obtained from the load factor of the items in each component show how much that item can contribute to measuring the components. The results show that the flexibility items generally have higher load factors. The expansion of the first item is less important than the other items (Figure 7)

Another aspect of test validity is convergent validity. Whenever two tests measuring a construct are correlated, then the correlation between them indicates that the constructed test is valid; therefore, two creativity tests (Torrance, CREE) have been used to examine the convergent validity, the results of the correlation between which are reported below. The Pearson correlation results showed no relationship between the total score of the Torrance Creativity Test in Form A and flexibility. In addition, there is a positive and significant correlation between this form and the components of originality, elaboration, and the overall score of creativity. Moreover, the amount of correlation obtained is moderate, indicating the convergent validity between this test and the creativity test in architecture. There is also a positive and significant relationship between the components of the Creativity Test in Architecture and Form B Torrance Creativity Test. The correlation between creativity in architecture and CREE creativity showed that only the elaboration component and the total score are correlated. There was no significant relationship between flexibility and originality with CREE creativity (Table 6).

After checking the validity, the reliability of the test was checked. Since the Torrance creativity test is scored on a continuous scale, the traditional Cronbach's alpha and Kuder Richardson methods are not used. One of the best methods is retesting, which is most consistent with the concept of validity, but because in this study, it was not possible to perform retesting, the split-half method was used. At first, based on the



Design issues: weather conditions, disabled access, shared wall between the prayer hall and the bathroom, sloping roof, communication path, entrance courtyard, exterior form, separate bathroom, It should be above ground, large window overlooking the sea, fountain, be consolidated, the building should be designed as linear.

Contradictions:

Consolidation ↑ Harmful factors on an object from outside ↓ (Principles 1-18-35-37)

Convenience of use ↑ complexity ↓ (Principles 32-26-12-17)

Efficiency ↑ Area of stationary object ↓ (Principles 10-35-7-17)

Ability to adapt to the environment ↑ Harmful factors on an object from outside ↓ (Principles 11-35-32-31)

Lighting ↑ Energy dissipation ↓ (Principles 13-16-6-1)

Temperature ↑ Energy dissipation ↓ (Principles 21-17-38-35)

Solutions:

Transformation of feature, leveling, copying, nesting, changing the color, direction change, equipotentiality

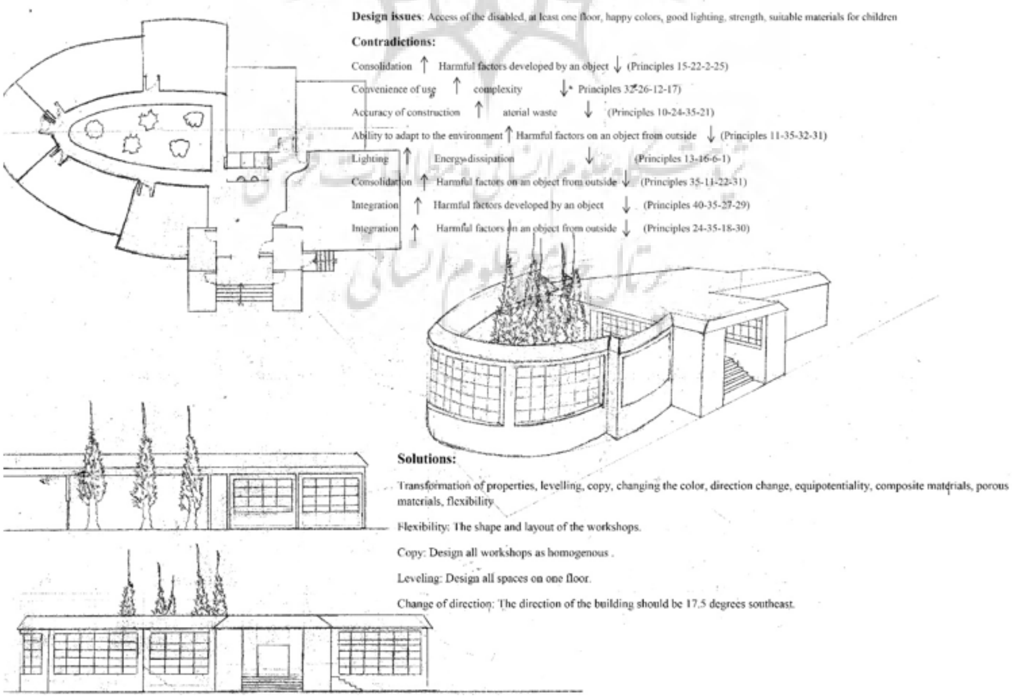
Leveling: All spaces should be designed in one level

Coping: Design all spaces symmetrically

Equipotentiality: The surrounding halls that both guide the person getting Wudu and prevent being wet.

Change of direction: The direction of the qibla is such that the northeastern part of the prayer hall is the resting place of passengers and the southwestern part is the place of prayer and they do not disturb each other.

Fig. 2: An example of a midway prayer hall practice



Design issues: Access of the disabled, at least one floor, happy colors, good lighting, strength, suitable materials for children

Contradictions:

Consolidation ↑ Harmful factors developed by an object ↓ (Principles 15-22-2-25)

Convenience of use ↑ complexity ↓ Principles 32-26-12-17)

Accuracy of construction ↑ aterial waste ↓ (Principles 10-24-35-21)

Ability to adapt to the environment ↑ Harmful factors on an object from outside ↓ (Principles 11-35-32-31)

Lighting ↑ Energy dissipation ↓ (Principles 13-16-6-1)

Consolidation ↑ Harmful factors on an object from outside ↓ (Principles 35-11-22-31)

Integration ↑ Harmful factors developed by an object ↓ (Principles 40-35-27-29)

Integration ↑ Harmful factors on an object from outside ↓ (Principles 24-35-18-30)

Solutions:

Transformation of properties, levelling, copy, changing the color, direction change, equipotentiality, composite materials, porous materials, flexibility

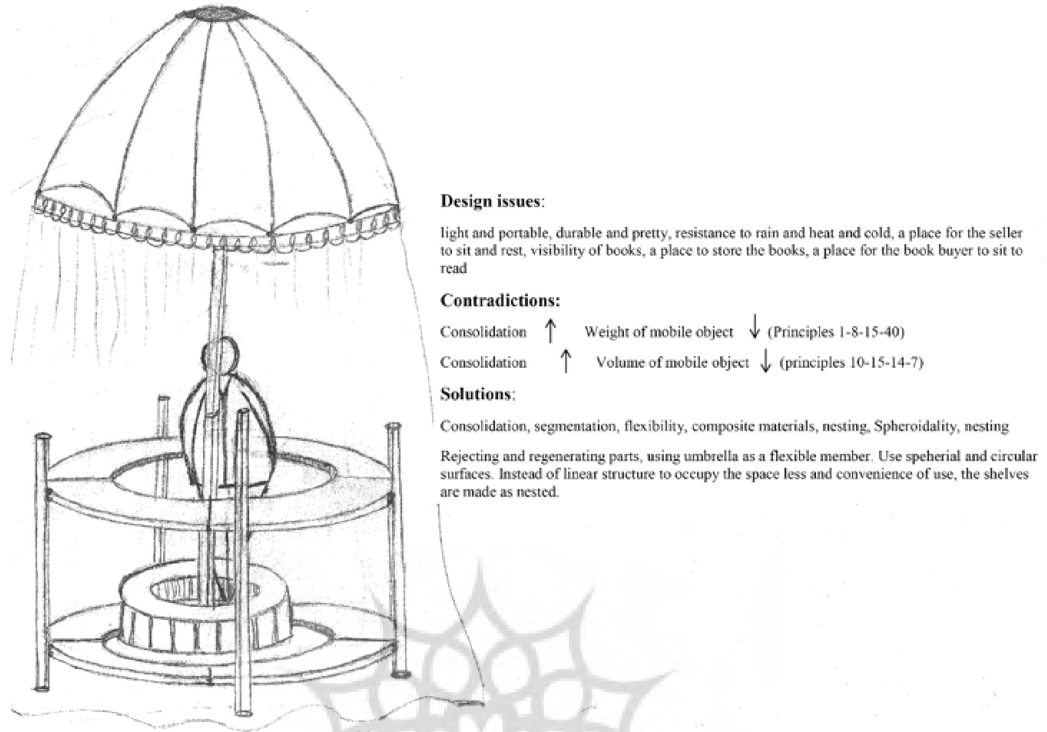
Flexibility: The shape and layout of the workshops.

Copy: Design all workshops as homogenous .

Leveling: Design all spaces on one floor.

Change of direction: The direction of the building should be 17.5 degrees southeast.

Fig. 3: An example of children's house in the park exercise



Design issues:

light and portable, durable and pretty, resistance to rain and heat and cold, a place for the seller to sit and rest, visibility of books, a place to store the books, a place for the book buyer to sit to read

Contradictions:

Consolidation ↑ Weight of mobile object ↓ (Principles 1-8-15-40)

Consolidation ↑ Volume of mobile object ↓ (principles 10-15-14-7)

Solutions:

Consolidation, segmentation, flexibility, composite materials, nesting, Spheroidality, nesting

Rejecting and regenerating parts, using umbrella as a flexible member. Use speherial and circular surfaces. Instead of linear structure to occupy the space less and convenience of use, the shelves are made as nested.

Fig. 4: An example of a Friday book market stall

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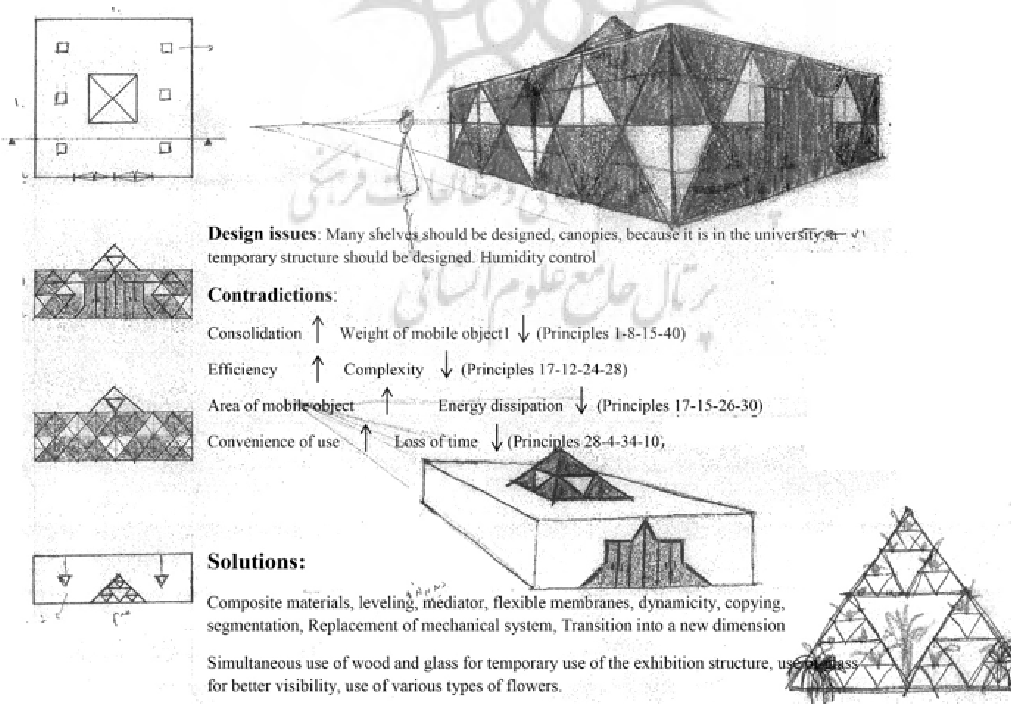


Design issues: Many shelves should be designed, canopies, because it is in the university, a temporary structure should be designed. Humidity control

Contradictions:

Consolidation ↑ Weight of mobile object1 ↓ (Principles 1-8-15-40)

Efficiency ↑ Complexity ↓ (Principles 17-12-24-28)

Area of mobile object ↑ Energy dissipation ↓ (Principles 17-15-26-30)

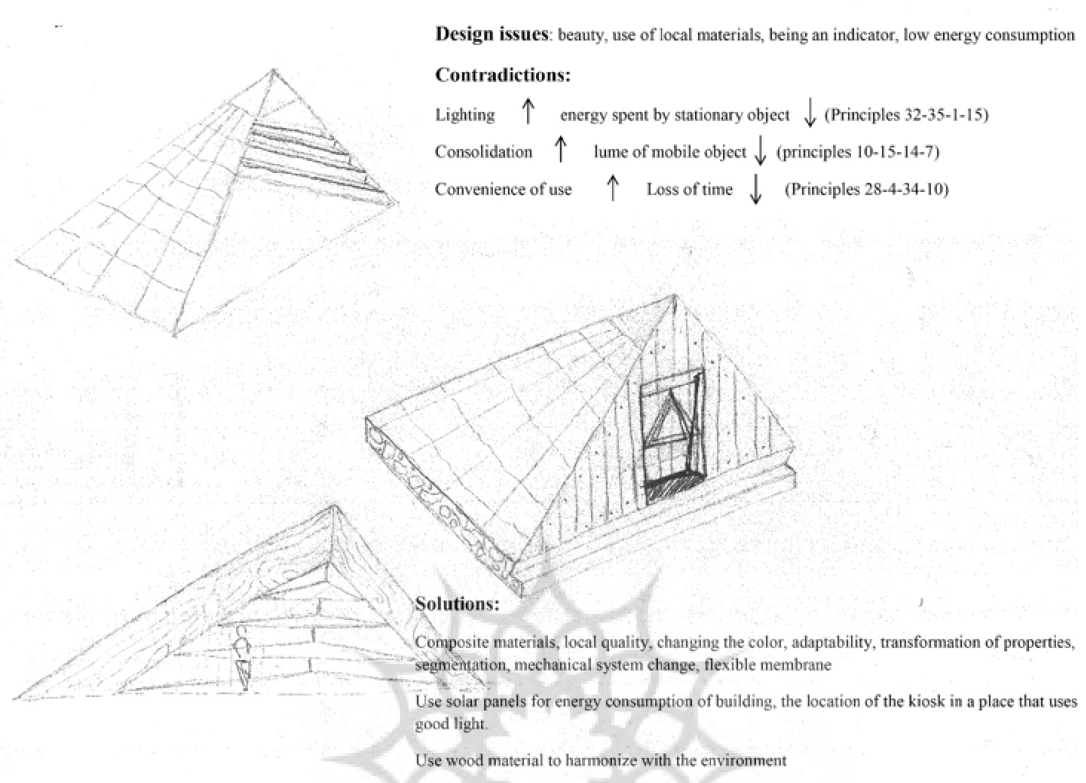
Convenience of use ↑ Loss of time ↓ (Principles 28-4-34-10)

Solutions:

Composite materials, leveling, mediator, flexible membranes, dynamicity, copying, segmentation, Replacement of mechanical system, Transition into a new dimension

Simultaneous use of wood and glass for temporary use of the exhibition structure, use of glass for better visibility, use of various types of flowers.

Fig. 5: An example of a flower and plant exhibition



Design issues: beauty, use of local materials, being an indicator, low energy consumption

Contradictions:

Lighting ↑ energy spent by stationary object ↓ (Principles 32-35-1-15)

Consolidation ↑ lume of mobile object ↓ (principles 10-15-14-7)

Convenience of use ↑ Loss of time ↓ (Principles 28-4-34-10)

Solutions:

Composite materials, local quality, changing the color, adaptability, transformation of properties, segmentation, mechanical system change, flexible membrane

Use solar panels for energy consumption of building, the location of the kiosk in a place that uses good light.

Use wood material to harmonize with the environment

Fig. 6: An example of a tourist kiosk

Table 5: Mean, standard deviation, skewness and kurtosis, factor loads, error and t value of items in flexibility, originality, and elaboration

Component	Item	Mean	SD	Kurtosis	Skewness	Factor load	Error	t-value
Flexibility	Friday book market stall	10.00	3.68	0.69	-0.30	0.72	0.58	4.59
	Tourism kiosk	6.78	2.99	0.31	-0.71	0.87	0.43	6.03
	Flower and plant exhibition	7.38	3.13	0.33	-1.16	0.71	0.50	4.49
	Mid-way prayer hall	7.38	2.77	-0.31	-0.78	0.85	0.40	5.83
	Children house	7.63	5.19	0.52	-0.55	0.94	0.71	6.85
Originality	Friday book market stall	15.88	6.41	0.45	0.08	0.72	1.17	4.42
	Tourism kiosk	13.22	7.24	0.66	0.38	0.54	1.35	3.05
	Flower and plant exhibition	10.59	6.61	0.99	0.56	0.51	1.17	2.88
	Mid-way prayer hall	14.22	6.54	0.13	-0.99	0.47	1.18	2.60
	Children house	14.56	7.08	0.55	-0.32	0.84	1.27	5.47
Elaboration	Friday book market stall	13.09	5.29	0.14	-1.34	0.29	1.23	2.03
	Tourism kiosk	17.19	6.89	0.40	-0.68	0.63	1.71	3.65
	Flower and plant exhibition	15.72	8.25	0.94	0.70	0.82	1.30	5.22
	Mid-way prayer hall	30.25	12.17	0.59	-0.36	0.69	2.04	4.11
	Children house	19.31	7.59	0.49	-0.40	0.84	1.64	5.38
N=32								

difficulty of the items, the items were randomly divided into two categories. This method is called random pairs. Then the reliability was estimated using the Spearman-Brown method. Items 1 and 4 in one half and items 2, 3, and 5 in the other half were placed in the elaboration component. In the originality component, items 2 and 4 were in one half, items 1, 3, and 5 in the other half, in the flexibility component, items 3 and 5 were in one half, and items 1, 2, and 4 in the other half.

In the whole test, items 1 and 4 of the elaboration component, items 2 and 4 of the originality component, items 2, 3, and 5 of the flexibility component were in one half, and items 2, 3, 5; 1, 3, 5, and 1, 4 were in the other half, respectively. The validity coefficient obtained for the component of flexibility, originality, elaboration, and the whole test was equal to 0.90, 0.80, 0.75, and 0.91, respectively, which indicates that the test has good validity. Only in the elaboration component is the validity of the test lower than in the other components. It should be noted that the validity of the test is between zero and 1, and the closer it is to one, the better.

CONCLUSION

The purpose of this study was to develop a tool for measuring the scale of design creativity in the course of architectural design as a creative product in architectural studios and to evaluate its validity and reliability to determine how useful this tool can be for measuring creativity in architectural studios. According to the background, creativity has fluidity, flexibility, originality, and expansion components, so this tool must measure these components.

To achieve this goal, a measurement tool was designed and prepared together with two questions were formulated to check its validity and reliability. The first question of the research was whether this tool could have the necessary validity. In this regard, findings suggested that data fit the conceptual model and the tool enjoys construct validity. The significance of factor loads indicates that all the exercises used in the tool can be a good indicator for measuring the components of Torrance's creativity or creativity in general. Also, regarding the second question, i.e., to what extent can this tool be valid? The validity coefficient obtained for the components of flexibility, originality, and expansion of the test's total score indicates that the test has good validity.

Due to the good psychometrics of this tool reported in the research, it is a valid tool with good validity that can measure the increase in the components of creativity in architectural design and can be used in educational and psychological research and architectural studios.

Creativity has multidimensional content, including person, environment, product, and process. The kind of educational interventions in the studios is very important to promote it, so different interventions should be done based on the students' abilities. To this end, continuous evaluation and appropriate reviews during the training process can play an important role in other dimensions. Therefore, having an appropriate evaluation system and mechanism for measuring creativity during the intervention process in the studios can play a very useful role in promoting creativity. Therefore, teachers in architecture studios must have sufficient knowledge of the content aspects

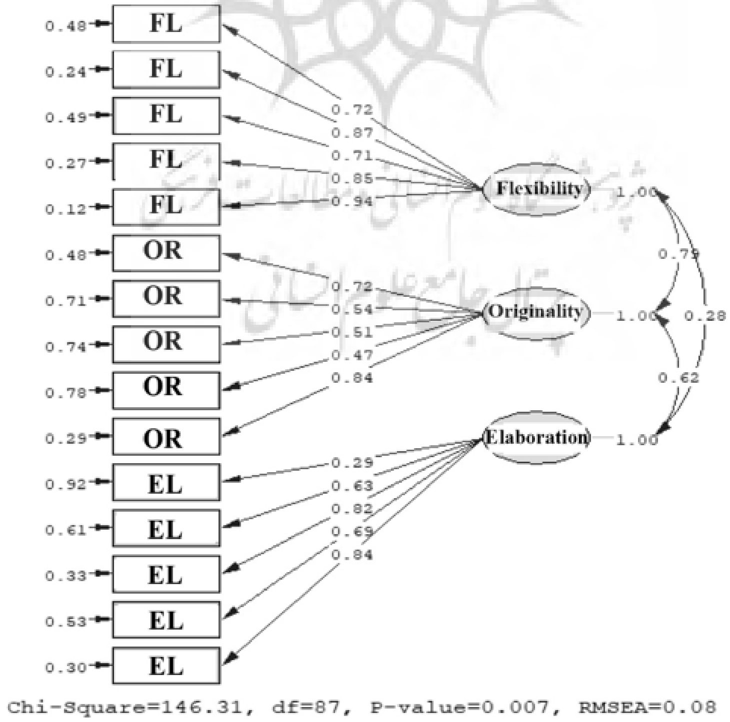


Fig.7: Conceptual model of Torrance creativity test

Table 6: Correlation matrix of Forms A and B Torrance Creativity and CREE Creativity with Creativity in Architecture

	Variable	Mean	SD	1	2	3	4	5	6
1	Flexibility	39.16	15.33						
2	Originality	69.34	25.68	0.65*					
3	Elaboration	98.31	35.62	0.26	0.57*				
4	Creativity	206.81	63.25	0.65*	0.88*	0.86*			
5	Torrance creativity (Form A)	241.06	66.75	0.31	0.50*	0.62*	0.63*		
6	Torrance creativity (Form B)	161.25	59.93	0.33**	0.55*	0.61*	0.66*	0.50*	
7	CREE creativity	62.88	17.27	0.12	0.30	0.39*	0.37*	0.32	0.41*

P < 0.01; ** P , 0.05; N = 32 *

of creativity to provide the conditions and context for their promotion and use appropriate educational interventions based on relative knowledge. This requires continuous evaluation to examine and correct the strengths and weaknesses of educational interventions. Achieving this requires credible tools to measure the creativity of the product of design interventions to help teachers. Therefore, the design creativity measurement tool made in this research can be effective due to its desirable psychometric properties.

Since professors and students have less used the Triz problem solving method that is used in this research, professors must be familiar with this theory before its employment.

In this article, an attempt was made to eliminate qualitative evaluations, and scoring challenges in design courses with the help of tools made based on Triz. By doing so, we can use quantitative analytical tools to evaluate creativity with good validity and reliability to solve existing educational problems and evaluate creativity in architectural studios.

Since the developed tool has acceptable validity and reliability, the results can be generalized. It is suggested that since the promotion of creativity is a systemic concept, the effectiveness of this tool, along with other content dimensions and educational interventions, should be examined with a combined approach.

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