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Design-Based Learning of New Structures: Integrity and Interface Approach to Improve the Architectural Design Ability*

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ABSTRACT

One of the most significant reasons for Iranian architecture failure is the lack of knowledge and applying innovation in novel structural systems technology in the design process. The architect must utilize the capabilities of new architecture, which requires his/her skill in the creative application of the modern structural systems in the design process. The purposive education of the novel structures course and its effective and functional application in the design process seems necessary to improve the skills in the architecture schools. The current research aims to explain the efficient educational solutions to improve architectural design skills based on design learning and structural novel technologies. This scientific approach is a reciprocal result of developing the ability to design and adopt a constructivist approach in the interactive learning of architecture students. In this regard, the current study is conducted to investigate the effectiveness of integrity and interface in the simultaneous integration of the new structures in the students' architectural design skills. The main research question is how to transfer practical and effective design-based learning of new structures in the architecture workshop and increase the design skill components. The research method is a sequential mixed method based on a quasi-experimental strategy. The research test was conducted in two phases of the pilot trial in the architectural design workshop as an interactive constructive learning environment. The statistical population of research consisted of third-semester master students of Islamic Azad University, Hamedan Branch, in three groups consisting of 15 people. One group was the main group, and two others were selected as the control group. The research data were collected based on the main components of research, and sequential tests were analyzed based on review criteria. The research findings in the pilot trial indicate that simultaneous learning of the novel structures in the commonplace of design atelier practically leads to the improvement of the main components of the design skills. It can also be employed as a practical pattern in the workshops of architecture schools.

Keywords: Design Ability, Constructive Learning, Transfer of Learning, Pilot Trial, New Structures.

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1. INTRODUCTION

Nowadays, the methods used in learning and practical application of new structures and transferring its creative application in design skills in the architecture schools are inefficient and ambiguous. Thus, neither effective knowledge is grasped nor has a desirable and practical impact on students' design process. Currently, new structures are taught based on teacher-oriented and theory classrooms separately, which is increasingly inefficient. On the other hand, architectural design skill in using creative forms of new technologies is decreasing, and there is a gap between the two approaches. Learning must be done in a way to increase the motivation and passion of students simultaneously in the design and structure area and its simultaneous smart usage, and monitor its impact on their design. Efficiency, sustainability, and aesthetics in architecture lead to a prominent architecture work when these three principles are integrated. Unfortunately, it has been neglected in the educational system of the country. Also, each of these principles is taught separately in academic curricula and parallel. Architecture education is consistent with the development of construction technology and new structural systems. Often, the learning oriented of technology and new innovations are not conducted integrated and effective in the design workshops in the architecture schools. Nowadays, due to the developments in theoretical knowledge education, there is a lack of integration between learning the theoretical subjects and acquiring the practical skills of architecture design.

Architecture education in design ateliers is of significant importance. Since the main purpose is learning and its effective application in the education process, the education is conducted properly when meaningful and practical learning was done to increase the skill and ability. It can be achieved in architecture by applying skill-based learning in the architecture workshop (Salama, 2005).

The current study aims to find the missing ring of the relevance and simultaneous learning and application of new structures and architecture design and its interactions and effects. Thus, in addition to constructive design-based learning of the structures, one can transfer them to the architecture workshop and improve the architectural design skills of architecture students. In other words, the design abilities and skills can be improved using integrity and interface in integrating design and structure. In this regard, this study seeks to answer the basic question that to what extent the simultaneous teaching of new structures in the process of architectural design and constructive design-based learning will affect the architecture students' design skills and ability components? This research's approach is to apply and explain the research model for simultaneous composition and continuity in the workshops of architecture schools in order to improve the skills in design ability.

2. RESEARCH METHOD

The current research approach is experimental with a quasi-experimental approach. It studies the causal relationship between variables, and its effect on the dependent variable of research is observed. Then, its results are extracted and analyzed by manipulating the variable in a controlled complex. The criteria and indices were validated in a comparative analysis between the main and control groups of the sequential tests in an organized framework in this research. Then, the researcher's hypotheses are proven. The numerical analyses are concluded based on ANOVA and Kruskal-Wallis tests and data normality. Assessment of ability performance is conducted by experienced reviewers based on determining the rank in evaluating indicators and determining the score in evaluating the test criteria. In the design and skill education in the behavioral sciences, the research is conducted qualitatively. Also, the research is conducted quantitatively on the indices and criteria of the new structures based on numerical analysis of tests. Therefore, the sequential mixed research method is the approach of the current study.

How does design-based learning of the new structures improve the main components of ability in design skills?

The research aims to explain an effective and practical educational model to improve the architectural design skill extracted from the integration in the functional learning of the new structures in the architectural design process.

3. RESEARCH BACKGROUND

There are scholars in the design ability of architecture, such as Dreyfus, Lawson, Dorset, and Donald Schon, who have investigated and classified the abilities and skills in design and developed its influential components.

Many scholars have studied the design ability and learning methods of structures and their influential applications. Among these scholars are Demirbas and Demirkan, who investigated the relationship between academic achievement and design ability in the design workshops based on quadruple loop learning of David Kolb (Demirbaş, 2003, p. 439).

Jian Ji and Adrion Bell developed the Seeing and Touching model at Manchester University of England in 1986. In this method, six main components of the structure were selected, and it was attempted to understand its concepts using the examples and models. It seems that this method has contributed to understanding the structural concepts and attracting and effectiveness of the learning in students (Ji, 2000, p. 28).

Moreover, another significant theory called "To Think in Architecture, To Feel in Structure" was developed at Slovakia University. According to this theory, an architect must feel what happens in a structure without

calculations and accurate numbers. The structure of famous masterpieces of the architecture world was used to advance this model at this university (Ilkovič, 2014, p. 99).
In another study conducted by "Kvan and Yunyun" that investigated the performance of architecture students in design workshops in 2005, concluded that if the type of practices given to students is consistent with their learning style in the practical workshop, there will be more effective evaluation and performance (Kvan, 2005, p. 30). Among the conducted studies in the technology and structure education is the Charter of UNESCO in 2005 (UNESCO, 2005). It is a charter for teaching architecture, especially the technical and technological aspects, which emphasizes studio design in the process of teaching and educating architecture.

4. CONSTRUCTION LEARNING

This learning originates from the scientists' scientific and philosophical thoughts, such as Piaget, Bruner, and John Dewey. The active role of the learner in understanding knowledge-making is emphasized in this type of learning. This type of learning is formed based on practical and structural concepts.

4.1. Learning

Gagne defines learning as follows: "learning is a change in human ability which remains for a while and cannot be easily related to the growth processes" (Seif, 1995).
Hilgard and Marquiz defined learning as follows:
"Learning means creating relatedly stable changes in the potential behavior of the learners if this change occurs due to experience" (Seif, 2007).

4.2. Transfer of Learning

Since learning is one of the purposes of any educational event, it cannot be the final purpose of architectural education, especially architecture design, as the purpose is to achieve ability and apply learning. "In the transfer of learning, the learning experience in a specific case affects the learning in another case".
In other words, transfer of learning is the application of previous knowledge in the process of understanding new concepts and solving new problems. "Transfer of Learning is implemented in two ways of positive and negative transfer. In the positive transfer, the previous learning facilitates the next learning. In the negative transfer, the previous learning disrupts the next learnings." (Seif, 2007).
One of the signs of transfer of learning is the ability to use information and skills to solve problems. What occurs in the process of problem-solving and design of work is the conscious or unconscious transfer of previous knowledge and experiences.
Two conditions must be taken into account to improve the transfer of learning that are as follows (Seif, 1995):
1. The use and various and diverse examples for better understanding
2. Improving metacognitive skills of students.

4.3. Studio-based Learning

Architecture education in design ateliers is of significant importance. Since in the education process, the main purpose of learning is to apply and transfer it practically, education is done properly when meaningful and constrictive learning occurs. It is achieved using the Studio-Based Learning method for architecture design students in a workshop. It is a precious method emphasized by prominent theorists, such as Donald Schon, Nigel Cross, Chris Argyris, and Lawson.
The SBL method is based on skill-based learning, i.e., the practical skillfulness becomes significant in the architecture workshop (Salama, 2005).
This method develops technical education and techniques for students through practical learning in the common workshop spaces directed by the instructor. Students are affected by the design thinking perspective of the teacher in practice. The design projects are long-term and are too replete that keep the students attracted. Solidarity and two-way friendship between teacher and student is the environmental and practical features of the SBL (Cross, 2006).
The SBL means the lifetime infusion of learning based on discovery, teamwork, integration, application, analysis, combination, and evaluation. Committing to the design tasks for sequential hours over weeks and months is a significant feature of the SBL. In this system, 12-20 students work under the supervision of a professor. They spend a great deal of their life and time in this space and ateliers. In the architecture design process, curiosity and questioning, discovering, analyzing, constant work, and integration of the various knowledge are done in the atelier. In other words, collective learning occurs. The design skill improves by the instructor's guidance. Boyer and Mitgang are among the prominent experts and theorists of the SBL.

Table 1. Global Experiences and Studies on the Learning Methods in the Architecture Design Workshops

Persian Title	Year	Researcher	Keyword
Digital Workshop in Architecture Design Process Education (Ismail, Mahmud, & Hassan, 2012, p. 24)	2012	Aref Ismail Mahmud Hassan Shah	Simulation Design Activities
Effects of Formalistic approach in architec-ture design (Mahdavinejad & Pourbaqer, 2013, p. 273)	2014	Mahdavinejad Pourbaqer	Formalistic Approach Workshop Design Learning

Persian Title	Year	Researcher	Keyword
Architecture Design Feedback; return of rationality to workshop (Bashier, 2014, p. 427)	2014	Fateh Bashier	Implicit Method Integrated Design
Tips on Architecture Training: An Experimental Approach to Design Workshops (Ciravoğlu, 2014, p. 8)	2014	Aysan Ci-ravoğlu	Architecture Education, Design Workshop, Freedom, Confidence
Architecture and design education in the international meeting of architecture students (Ertas & Samlioglu, p. 152)	2015	Sinem Ertas Samlioglu	Architecture Education Practical Workshop
Architecture education, project design course, and education process using examples (Dizdar, 2015, p. 279)	2015	Safieh Everm	Architecture Education of Workshop design
The importance of educational tools for formal workshop studies in teaching architectur-al design (Kuyrukçu & Kuyrukçu, 2015, p. 2669)	2015	Emine Kuyrukcu, Idliz Kuyrukcu	Architecture Education for Formal Workshop Studies
Using the blog as a communication tool to educate students in the architectural design studio (Bâldea, Maier, & Simionescu, 2015, p. 2760)	2015	Maja Baldea, Alexander Mier	Use of Blogs Architecture Training Tools Design Studio
Modeling Design Problems by Solving a Problem in an Architectural Design Workshop (Nazidizaji, Tomé, & Regateiro, 2015b, p. 2025)	2015	Nazidizaji, Tomé	Design Workshop
Searching for the Concept of Tirilieh: An Ar-chitectural Design Studio (Sagdic & Degirmenci, 2015, p. 980)	2015	Zafar Sagdic	Design, Architecture, Creative Thinking,
Do smart designers design better? The effect of intelligence on students' design skills in architectural design workshops (Nazidizaji, Tomé, & Regateiro, 2015a, p. 320)	2015	Sajjad Nazidizaji, Ana Tome	Architectural Design Workshop IQ Design Thinking
Factors Affecting the Performance and Form of Design Decisions of Students of Interior Architecture Design Workshop (Karslı, 2015, p. 1093)	2015	Amut Tuglu	Design Workshop Interior Architecture Education Design process Design methods
The effect of multiplying the cost by the basis of architecture design education; Analysis of the basis of design in the workshop (Lee, Tabb, Rogers, Rybkowsk, & Van Zandt, 2016, p. 928)	2016	Li et al.,	Cost, Basis of the Studio Architecture Design

5. ARCHITECTURE DESIGN ABILITY

Ability: skill in relating specific information and its application to complete the work and finding a proper solution for it.

Knowledge + skill = Design ability

In other words, design is a type of skill. In the process of obtaining skill, ability plays the most significant role (Lawson, 2006).

Introduction or the specific information, Including facts, Definitions, Concepts	Knowledge
Understanding and absorbing information	Understanding (Insight)
Skill in relating the information and its application	Ability (Potency)

Design ability consists of a set of skills classified into "formulation, developing idea and solution, representation, evaluation, reflection in practice, framing, visualization, and transferring practical concepts" (Lawson, 2009).

The above are considered the main components of skill in design ability in the current study. Design ability is one of the main types of ability and is considered an aspect of the human's cognitive abilities. Each person enjoys some extent of this ability. However, most professional designers developed their design ability through education and experience in its specific place, i.e., architecture ateliers. However, generally, architecture education lacks a specific method of acquiring ability and its degrees (Talischi, 2011). A proper "educational design" must be planned for the ideal and appropriate ability in design. Educational design is the prescription of the desirable methods to reach the knowledge, disciplines, skills, and ability of design students. There are various approaches

for educational design classified into two groups of objectivist and constructivist. In objectivist educational design, the education purposes are expressed very specifically, and the learning and teaching methods are predicted. The constructivist design consists of providing the environment, resources, and support in the learning processes. It also significantly emphasizes the active participation of the learner and ability. Among these two approaches, the constructivist approach seems appropriate for developing architecture design ability education (Herr, 2013, p. 100). The architecture ateliers are the constructivist learning environment.

6. NEW STRUCTURES EDUCATION

Paying attention to establish a relationship between structure concepts and architecture is of significant importance. Familiarizing architecture students with new structures and using the pioneer architects' and engineers' experiences in using new structural technologies in academic education seems necessary.

6.1. History of New Structures Course

New structures course, as one of the optional courses, has been defined in the curriculum of the architecture in undergraduate and graduate degrees. The main purposes of this course are as follows:

- Familiarizing architecture students with new structural systems.
- Analysis of the performance and behavior of various new structural systems in different loading conditions.
- Developing required ability in students for the appropriate application of the new structural systems in architecture projects design in the school and professional environment.

6.2. Investigation and Pathology of New Structures Education

Theoretical and teacher-oriented education or presenting slides, images, and even making maquettes will not be useful alone. Indeed, its impact and two-way integration with architectural design courses and starting the concept of design by understanding and applying different new structures in terms of form and structure will be effective. Therefore, two main purposes are as followed:

1. Design-based learning of new structures
2. Improving the ability of architecture design using new structures

The failure of architecture students in interacting with structure and architecture design depends on three factors (Herr, 2011): curriculum of structure and design courses, education and learning methods, educational tools.

If the education method of structures is based on the engineering discipline, it will lead to disinterest and inaction in the architecture students due to the mathematical models and numbers. Thus, it will result in failure in acquiring the ability in design. The design workshop is a place to transform the learned concepts into novel ideas. Therefore, the forms and concepts of modern structure play a significant role in the formation of ideas and design processes.

6.3. Structure Education Methods

The learning and education process is effective when the education is based on the scientific theories, proper methods, and application of the required tools in this process. Architecture education is not an exception as a part of higher education. The education of the structural course in the architecture faculties in Iran has been more theoretical and lacks any practical professional experience. Therefore, the result of such an education will be the education of people with high mental abilities, and the possibility of practicing and creativity in professional works of architecture graduates is less. The education of structure is a significant part of the education process in architecture. Various educational methods in teaching construction technique area in architecture have been presented theoretically, scientifically, workshop, or a combination of those. Various education methods of the structure must be investigated considering the needs of students and graduates of this discipline to achieve a proper educational process. Then, better methods must be developed more as the main education methods.

Table 2. Global Studies and Experiences of Structure Education (Based on Method)

Row	Conducted Studies Regarding Structure Education	Theorist	Year	University/ Country	Method Description
1	Traditional Education Model (Theoretical)		-	Iran	This method is more applied in the developing architecture faculties. This method is often presented by structure experts as teachercentered classrooms or speech.
			1975	Berkeley, California	
2	Using Conceptual Modeling and Natural Structures to Teach Structural Concepts	Komendant	1975	Nigeria	In this method, the structural concepts are taught physically and tangibly to students.
		Mojtaba Ansari	2010	Iran	
		Mahmoudi Kamelabad	2006	Iran	
3	Based on Fundamental and Profound Understanding of Structure and Using Scientific Activity	Christopher	2003	Virginia	In this model, a profound and fundamental understanding of structure is created in student without any complicated calculations to be able to use them in design.
		Christian Herr	2013	Liverpool/ XJTLU	

Row	Conducted Studies Regarding Structure Education	Theorist	Year	University/ Country	Method Description
4	Using Multimedia Space for Understanding Structural Concepts	Vasigh	2005	New York	This method attempts to use graphic capabilities to improve the understanding of the fundamental structural concepts.
		Soleimani	2014	Iran	
		Molanai	2014		
		Teresa Ramsey	1996	Virginia	
		Kirk Martin	-		
5	Making a Maquette of the Implemented Structure in the Work to Understand the Structural Concepts	Siegel	1975	New York	In this model, after teaching the theory of static lessons, students are asked to make a maquette by modeling new structures implemented in the world.
6	Using Model and Maquette to Understand the Fundamental Structural Concepts	Bell and Jian Ji	2004	England	To understand the basic structural concepts, it is necessary to have the conditions in which these concepts can be seen and touched.
		Azizzadeh et al.	2016	Iran	
		Lemon	2010	Boston	
		Christian Herr	2012	China	
7	Nature and Structure Education	Christopher	2003	Virginia	One of the most significant methods is the simulation and replication to the environment.
		Zamani		Iran	
		Mahmoudi Kamelabad	2000	Iran	
		Ansari et al.	2010	Iran	
		Shahroudi	2008	Iran	
		Taghizadeh	2007	Iran	
8	Problem-Solving Based Teaching Method	Slovak University of Technology	2008	Slovakia	This method describes how structural concepts can be introduced in a classroom that can be seen and touched using simple physical models.
9	Using Arch-ST method	Molanai	2014	Iran	
10	Using mixed methods	Shahroudi	2009	Iran	Based on this educational hypothesis, quantitative scientific methods can be more effectively integrated with qualitative and conceptual methods and both can be used in the scientific aspects of building design.
		Golabchi	2004	Iran	
11	Simulation	Bastanfard	2012	Iran	This method is in the form of real simulation and virtual simulation.

The main education structure of the new structures is based on the analysis of new structures systems, features, applications, classifications, and types of systems in terms of form, function, geometry, force, and dimensions. The current methods of structures education are incapable of transferring the practical concepts to architecture students, the research for which can be explained as follows (Vasigh, 2014):

A) The process of structure education and applied educational tools are mainly adapted from engineering programs with a slight change. Also, the education is very quantitative and abstract.

B) Education of the new structures is conducted separately from other courses, especially architecture design, and lacks the practical effectiveness.

C) The proper and applied methods are not used to learn the technical subjects.

D) The current education is conducted in the form of teacher-centered and based on the theory and speech.

E) The lack of innovation and creativity in the intelligent application of new structural forms in the architecture design process.

Considering the above and lack of the practical effectiveness of the new structural systems in the design ability skills, the main basis of this paper is formed based on the design ability and complete and effective relevance of skill along with new structures knowledge. The main purpose of the current study is to investigate the effectiveness of the design-based learning indices of the new structures in the main components of the design abilities.

7. THEORETICAL FRAMEWORK

- Design-based learning:

A) Learning process, B) Learning environment

Learning process indices are as follows:

1. Discovery and questioning
2. Motivation and interest

3. Reflection
4. Analysis
5. Problem solving
6. Creativity
7. Application

Indices of the learning environment are also as follows:
1. Interactionism
2. Collective learning
3. Pragmatism

- New structures:

New structures consist of two parts of components indices and structure's components:
A) Indices of components include the following:
1.Form, 2. Implementation, 3. Proportions, 4. Behavior, 5. Geometry, 6. Dimensions, 7. Application.
B) Structure's components also consist of the following:
1. Recognition, 2. Understanding, 3. Analysis, 4. Application, 5. Transfer.

- Design ability

In general, design ability is analyzed based on the following factors:
1. Framework, 2. Representation and visualization, 3. Axial solution, 4. Formulization, 5. Process-oriented, 6. Evaluation, 7. Contemplation in practice, 8. Cooperative activity, 9. Learner-oriented, 10. Applying what have been learned, 11. Transferring the practical concepts, 12. Improving interest and motivation.

The indices and components extracted from the literature review were developed in three main areas of research. Also, the research framework was explained considering the main question and research hypothesis and purposes. "The main research purpose is to achieve an efficient and influential model to improve the components and skills of the design ability resulted from the constructive design-based learning of the new structures".

In this regard, the researcher attempted to determine, analyze, and explain a scientific and research method in the form of two sets of quintet main and experimental tests, relationships, and the effectiveness of the codified indices and components. Thus, by investigating the interactive effect of constructive learning indices and factors in the new structures' components, one can study and analyze the degree of improvement of the indices and criteria of various skills in the ability.

8. RESEARCH METHOD

Given the theoretical framework and the main purpose of research, as well as the effectiveness of the constructive learning of the new structures to improve the design ability of the architecture students, the following hypothesis can be raised:

Integrated, simultaneous, and interactive relationship of the architecture design, application of the new structural systems in the design process, and the architecture workshop as a shared place can improve the main components of the skill in the design ability of the architecture.

A control group and a quasi-experimental research plan were used in this study. This type of design where the selection and assignment of the subjects are not random is called "pretest-posttest design with non-equivalent groups" (Sarmed & Bazargan, 2008).

In this method, the dependent variable is measured before manipulating the independent variable. Then, it is calculated again after implementing the experiment and manipulating the variable. In this paper, the new structures learning components are considered independent variables affecting the architecture design ability indices as the independent variable. The current research purpose is to investigate the new structure variable effectiveness in the students' design ability as the dependent variable. Six components and three indices with impact factor were considered to assess subjects' ability in the pilot test.

Table 3. Evaluation and Investigation Method of Variables– First Semester of 2016-2017 (Pilot)

Group	Manipulating Variables	Independent Variable	Post-Test
Control Group (A) Control Group (B)	Assessment of design skill based on the common educational planning	Typical education method	Evaluation of the subjects' performance at the end of the semester- Fall 2016
Experiment Group (Main)	Assessment of the design skill based on the theoretical framework of research	The proposed education method (synchronicity of the new structures education and architecture design)	

8.1. Subjects (Pre-Test- Pilot)

In the first phase, 15 subjects were selected as the main group (test) among the master students of architecture of the Islamic Azad University, Hamedan Branch. Also, 30 students (2 groups of 15 students) were selected as two control groups.

Selection and assignment of subjects were conducted through the unit selection system of the Islamic Azad University, Hamedan Branch. All the students of the main group and control groups considered in the pilot test have taken the architecture and design (1) course. Three groups of 15 master students of architecture were selected versus the main group of 15 students and two control groups of 15 students (30 students) for a pilot test in the first semester of 2016-2017. Some important points must be taken into account to provide the context for the pilot tests in this study. The number of the students in three groups must be selected equally, random, and by the system. The test group instructor, the researcher, and instructors of the other two groups (control) were selected among the experienced teachers

in this subject. Reviewers determined and explained by the equal criteria, based on the idealization of the test context and considering the equality of the educational environment, the instructors of the workshops, subject and homework of tests, the number of students in each group, and standardization of the variables and components. 45 students in three main, A, and B groups will be compared in this subject. Given the type of comparison and the number of groups, ANOVA parametric test and Kruskal Wallis nonparametric test will be used to compare. ANOVA test or one-way variance analysis is used for the mean comparison of a quantitative variable between more than two independent groups. Considering that three experiment groups (one main group, and two control groups) were used in this study, a t-test cannot be applied. In the ANOVA test, the variables are quantitative, and the average of the data is normal (lacks a significant difference). Due to the number of the test groups and the significant difference in the three groups' data, the Kruskal Wallis test was used in some tests of this research. ANOVA or Kruskal Wallis tests depend on the normality of the data. According to the statistical criteria, if the data are normal, a parametric ANOVA test will be used. If the data are not normal, the nonparametric Kruskal Wallis test will be used to compare the data. One must test the establishment of statistical presuppositions before conducting the single-variable and multivariable statistical analyses. If the deviation is partial in the statistical presuppositions, it can be ignored with tolerance and continue the analysis. However, if the deviation is considerable in the statistical presuppositions, data transformation methods must be used to re-establish the presuppositions, or the alternative tests must be used which do not consider the above presuppositions (Habibpour & Safari, 2009).

The concept of normal distribution applies to parametric data (not nonparametric data). The normality test examines a hypothesis of whether the research observations follow a normal distribution by creating a probability normality graph (symmetric to the mean). There are several methods for diagnosing data distribution status (normalcy status) (Habibpour & Safari, 2009). In this study, the Kolmogorov-Smirnov test will be used for this purpose, and consequently, Kruskal-Wallis or ANOVA comparison test will be selected to compare three groups (main group and two control groups). In order to evaluate students' ability performance variables, a proper and ideal method must be determined for learning and improving the architecture design ability. This method must enjoy the valid indices and criteria for evaluation and assessment. This research's proposed mechanism is the assessment of the ability performance of the master students of architecture by determining rank in the evaluation indices and determining the score in the assessment criteria by a board of experienced reviewers. Accordingly, the main variables of research were determined in two main groups of evaluation indices of the design process in six sections and evaluation criteria of design and new structures in nine sections.

Table 4. Evaluating the Variables of the Components and Indices of the Research Pilot Test

Evaluation of Pilot Test										**Subject/ Date**			
Components of the Simultaneous Evaluation of the Design and New Structures										**The Total Index with Impact Factor**			
Innovation and Idea Creativity	Innovation in the Structural form and Architecture	Function and Application	Transfer of Learning of the Structure to the Design Workshop	Effective Combination of Structural form and Architecture	Ability to Analyze	Evaluation of Scores Out of 5	Constant Presence in Sketches of the Tests	Simultaneous Advance of Design and Structure	Final Presentation	Impact Factor (0-1)	Impact Factor (0-1)	Impact Factor (0-1)	Final Score of Test
A													
B													
C													
Descriptions:													

Considering that the design ability consists of a set of skills, it is classified into "Formulization, generating idea, presentation, evaluation, reflection in practice, framework, visualization, transfer of practical concepts" (Lawson, 2009). The above mentioned are considered and evaluated as the main components of design in the design ability.

A) Generating Idea: the main skill of designers is generating the design solution. Designers are solution-oriented and attempt to generate the idea regarding the partial or general solutions. Sometimes, the mentioned solutions are developed or abandoned. This group of skills by which the solution is generated is called "Idea".

B) Presenting: the solution ideas are often presented through various ways of representations. They can be described by words or by various ways of drawing, modeling, and visualization. This type of skill can be called "presenting".

C) Formulating: Although there is a complicated relationship between design solutions and their corresponding problems, there is another set of skills by which designers understand and describe the issues. These skills are called "formulating".

D) Evaluating: evaluation and investigation of solutions are conducted by various assessment ways. It is implemented using implicit or relatively ambiguous criteria. Therefore, there is a full range of design skills which can be called "evaluating".

E) Reflecting: in addition to the mentioned skills, designers also supervise the whole design process and attempt to advance it. Designers make more or less conscious efforts in managing all design activities to guide the design process to the desired result. The components presented in Tables 4 and 5 are based on the five main indicators of ability skills and research structure diagram.

Table 5. Evaluating the Variables of Research Test Criteria and Components

Assessing the Architectural Design Ability of the Pilot Test												
Evaluation Criteria of Design and New Structures												
	Design-based Learning Component	Recognition of New Structure Systems	Innovation and Creativity in Designs Idea	Innovation in Designing form and Structure	Transfer of Practical and Purposive Concepts in Design Workshop	Application of Structure in the Architectural Design Process	Application of Structural Principles in Design	Effective Combination of New Forms of Architecture and Structure	Performance Analysis of Structures	Considering form and Geometry	Average of Ranks	Ranking Based on the Average of Ranks
Design Ability Component		Formulating and Framing	Presenting-Visualization	Presenting-Modeling Ideas	Applying Learned Knowledge	Solution Orientation-Process Oriented	Transfer	Reflection in Practice- Cooperative Activity	Formulating	Formulating-Framing		
Row	Rank										Σ	Y
A												
B												

8.2. Research Test

Five purposive tests (sketches) were implemented in an accurate interval to obtain the codified indices and criteria based on the approved curriculum and the specialized opinions of the expert reviewers. The considered tests were checked during the academic semester and based on the main subject of Design (1) course of the master of architecture on the international expo design.

Table 6. Research Tests Program (One Main Group and Two Control Groups)

Phase	Week	Session	Day	Date	Subject	Time	Descriptions
Pilot (1)	Second	First	Wednesday	2016-10-05	Designing the Overall Scheme of the Expo Booth of 2020	6 hours	
Pilot (2)	Fifth	Second		2016-10-26	Designing the Entrance of the Expo Exhibition	5 hours	
Pilot (3)	Seventh	Third		2016-11-09	Designing the Main Element of the Complex	5 hours	
Pilot (4)	Ninth	Fourth		2016-11-23	Interior Design of Iran's Booth in Expo	One week	
Pilot (5)	13th	Fifth		2016-12-21	Landscape and Environmental Design of Exhibition	6 hours	
Final Pilot		14 Sessions of Semester		March 2017	Design (1) of the Master of Architecture Iran's Expo in Dubai 2020	The Process of an Academic Semester	Final Evaluation of the Pilot Test in an Academic Semester

8.3. Review Method

First, all the students' designs were coded. Then, each reviewer evaluated the results of the students' designs. The reviewers rated each of the evaluation indices on a scale of 1 to 10 and each of the evaluation criteria on a scale of 1 to 5. After completing the steps, the reviewers' mean scores were set in specific tables and analyzed statistically.

9. RESEARCH FINDINGS

According to the conducted analyses, there is a significant difference between three studied groups in all subjects in two indices of "transfer of practical and purposive concepts to the design workshop" and "application of structure in the architecture design process". It indicates the significance of the new structures approach and its effectiveness in the design process. Also, there is a difference in at least three subjects of five subjects in other indices. In the following, each index is investigated in three groups in detail.

- Pilot test (1) – Subject: "designing overall scheme of expo booth 2002"

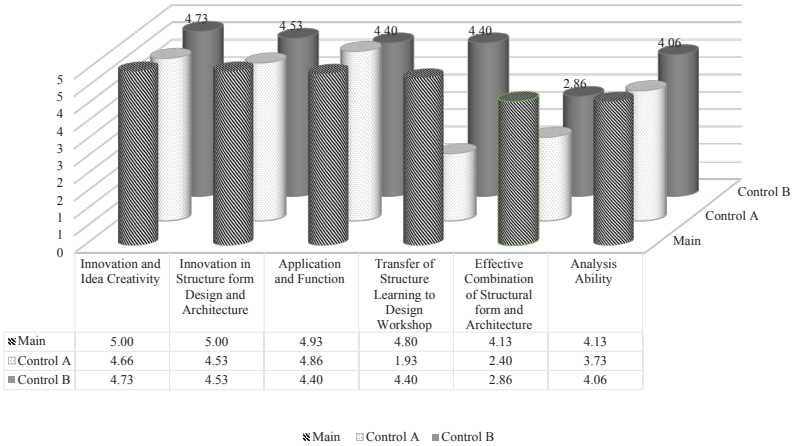
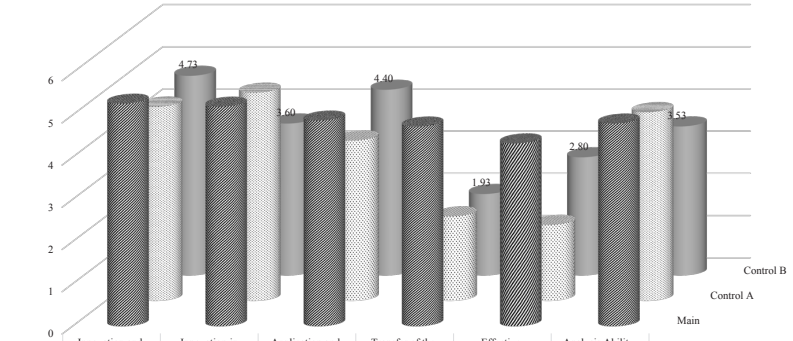


Fig. 1. The Scores' Average of the Pilot Design Indices in Test Groups with Subject of "Designing the Overall Scheme of Expo Booth 2020"

Furthermore, it can be seen that the average of the scores of all the indices in the test of the main group has been higher than the control groups of A and B. By comparing the A and B control groups, the average of the obtained scores by Control Group A was relatively better in "Function and Application" than the Control Group B. Also, the obtained scores in other indices by Control Group B have been better than other groups.

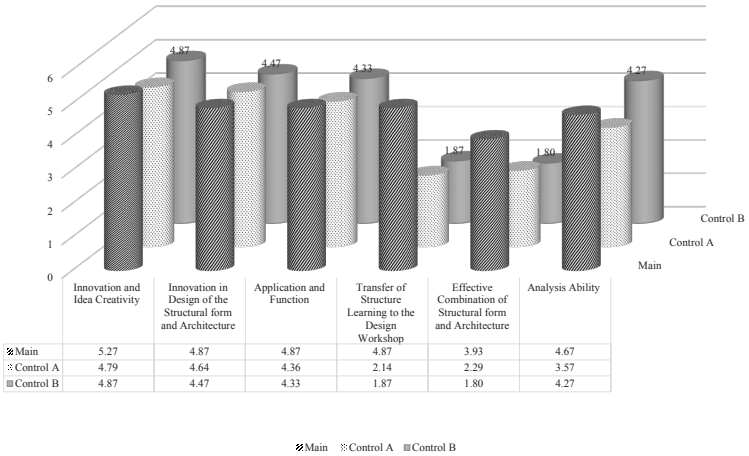
- Pilot test (2) – Subject: "Designing the entrance of the Expo Exhibition Complex"



	Innovation and Idea Creativity	Innovation in Structure form Design and Architecture	Application and Function	Transfer of the Structure Learning to the Design Workshop	Effective Combination of the Structure's form and Architecture	Analysis Ability
Main	5.27	5.20	4.87	4.73	4.33	4.80
Control A	4.60	4.93	3.80	2.00	1.80	4.47
Control B	4.73	3.60	4.40	1.93	2.80	3.53

Fig. 2. The Scores' Average of the Indices of Pilot Study in Test Groups with the Design Subject of "Designing the Entrance of the Expo Exhibition Complex"

The average of the scores of all indices in the test of the main group has been higher than control groups A and B. Also, by comparing the A and B control groups, it was revealed that the average of the obtained scores by control group A in "innovation in design form", "transfer of learning of the structure", "analysis ability" was higher than the control group B. Considering other indices, control group B has had better scores than other groups.

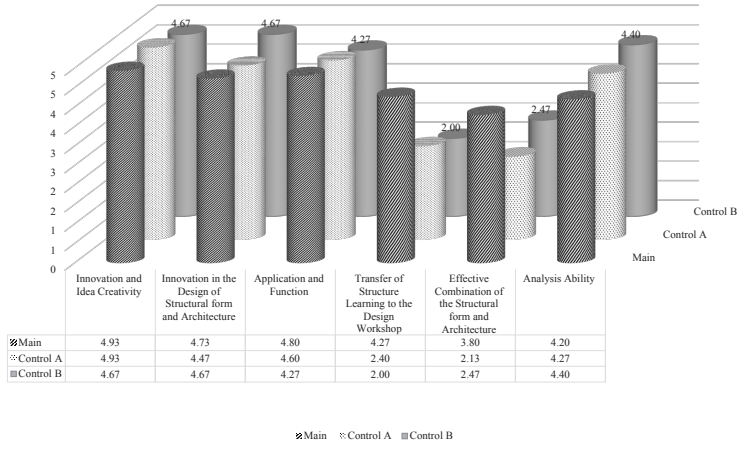


	Innovation and Idea Creativity	Innovation in Design of the Structural form and Architecture	Application and Function	Transfer of Structure Learning to the Design Workshop	Effective Combination of Structural form and Architecture	Analysis Ability
Main	5.27	4.87	4.87	4.87	3.93	4.67
Control A	4.79	4.64	4.36	2.14	2.29	3.57
Control B	4.87	4.47	4.33	1.87	1.80	4.27

Fig. 3. The Scores' Average of the Indices of Pilot Study in Test Groups with the Design Subject of "Designing the Main Element of Expo"

The average of the scores of all indices in the test of the main group has been higher than control groups A and B. Also, by comparing the control groups A and B, it was revealed that the average of the obtained scores by control group A in "innovation in design form", "transfer of learning of the structure", "effective combination of the structural form and architecture" was higher than the control group B. Considering other indices, control group B has had better scores than other groups.

- Pilot test (4)- Subject: "Interior design of Iran exhibition space"



	Innovation and Idea Creativity	Innovation in the Design of Structural form and Architecture	Application and Function	Transfer of Structure Learning to the Design Workshop	Effective Combination of the Structural form and Architecture	Analysis Ability
Main	4.93	4.73	4.80	4.27	3.80	4.20
Control A	4.93	4.47	4.60	2.40	2.13	4.27
Control B	4.67	4.67	4.27	2.00	2.47	4.40

Fig. 4. The Scores Average of the Pilot Design Indices in Test Groups with the Subject of "Interior Design of Iran Exhibition Space"

Except for "analysis ability", the average of the scores of all indices in the test of the main group has been higher than control groups A and B. Furthermore, by comparing the control groups of A and B, it was revealed that the average of the obtained scores by control group A in "innovation and idea creativity", "application and function", and "transfer of learning of structure" has been better than control group B. However, the obtained scores by control group B were better in other indices.

- Pilot test (5) – Subject "Landscape and Environmental Design of Exhibition"

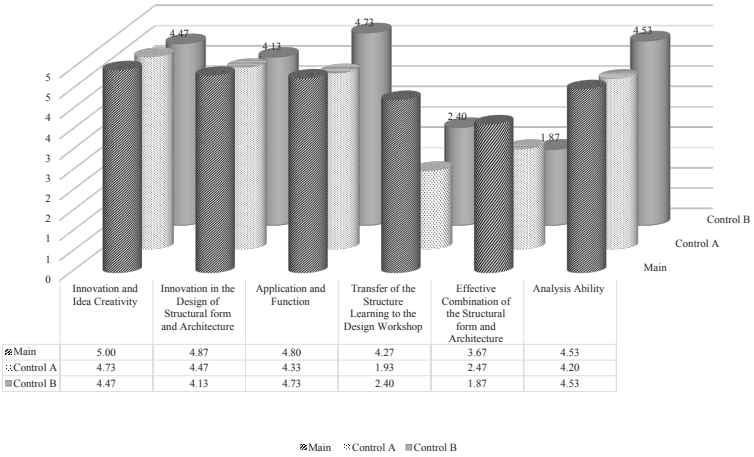


Fig. 5. The Scores Average of the Pilot Design Indices in Test Groups with the Subject of "Landscape and Environmental Design of Exhibition"

The average of the scores of all indices in the test of the main group has been higher than control groups A and B. Also, by comparing the control groups A and B, it was revealed that the average of the obtained scores by control group A in "innovation and idea creativity", "innovation in form design", "effective combination of the structural form and architecture" was higher than the control group B. However, the obtained scores by control group B were better in other indices.

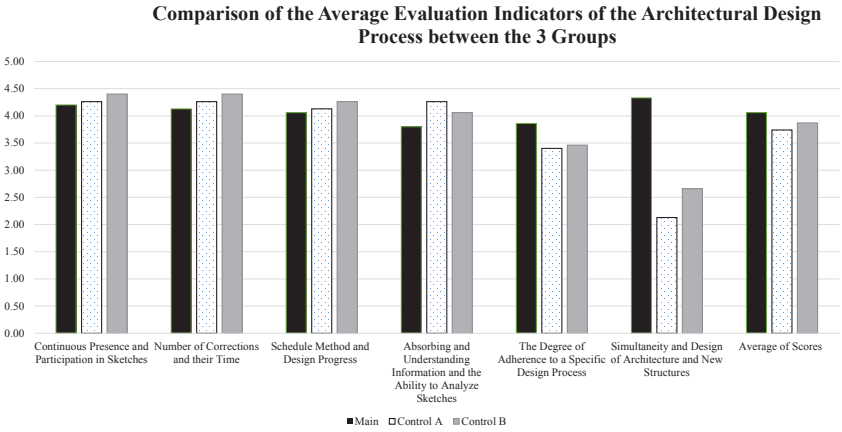


Fig. 6. Comparison of Evaluation Indicators of the Architectural Design Process of the Pilot Test

9.1. Discussion

This research was conducted to achieve a model for the integrity and interface learning of the new structures in the architecture design workshop and based on the research tests. Therefore, by integrity and interface approach, the structural new knowledge and design ability skills were integrated, improving it. The considered model was analyzed by scientific and accurate tests and considering the assessment criteria based on the detailed results of graphs.

According to the main research hypothesis and accurate investigation of the tests, the findings indicate that the performance of the main group's students has a significant advantage over the control group students in all review criteria, including main components and criteria of research. Given the scrutinizing of the scientific research results, it was revealed that the components of the research tests have a significant difference between the main and control groups.

According to Tables 4 and 5, the separation of the evaluation indices and evaluation criteria was analyzed by the accurate components of tests based on the assessment criteria and ranks. As can be seen in the graphs, the tests were evaluated on the scales of 0 to

5. Considering the validity and criteria of review and significant correlation of research components and indicators and with the main purpose of investigating how the integrity and interface of learning new structures on the rate of ability improvement in the architectural design process, the following diagram shows the comparison of ability components.

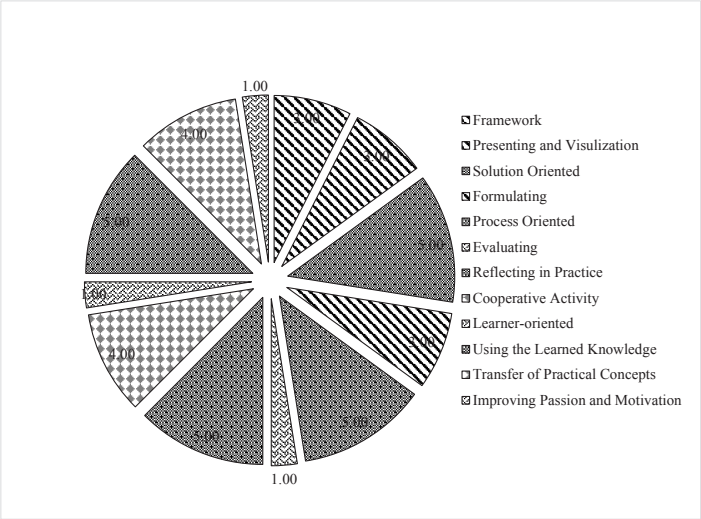


Fig. 7. Evaluation of the Improvement of Architectural Design Ability Components (Resulted From Pilot Test)

9.2. Research Proposed Model (Based on the Results of Pilot Test)

What must be considered as the innovation in the structures education is the different model of learning new structures and architectural design in a common workshop as the integrated practical learning based on the workshop in the same time and place in the form of integrity and interface approach. Furthermore, the transfer of the design-based learning of the new structures from the beginning of the design process in a constructive way to improve the architectural design ability and effective and practical application of the new structures system knowledge are of the features of this model. In this method, the up to dated knowledge of the structure can be effective in all the design process phases from the first step (idea formation) to simultaneously advance the idea and creativity with the facts of today's technologies of the world. While improving the practical learning of the structures, this model can transfer them to the design workshop. Also, in addition to becoming significant in the design since the idea formation, it leads to the improvement of the skills in the design ability of the architecture students.

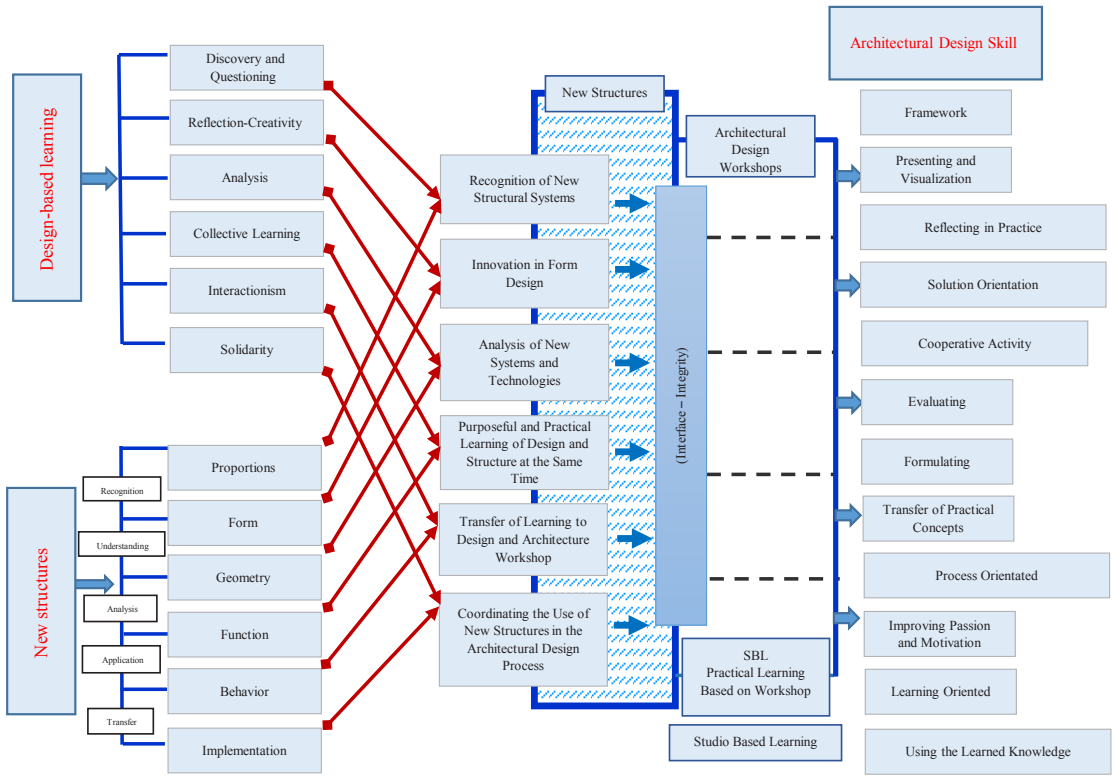


Fig. 8. The Proposed Mode of the Research

According to the conducted study, it is recommended that based on the considered model, the following be obtained by the combination and integration of the design-based learning main components and new structures in the shared place of the architecture design workshop.

1. Practical and purposive learning
2. Analysis of the new systems
3. Recognition
4. Innovation in the form design
5. Transfer to the workshop
6. Consistency in the design process

Eventually, the main components of the skill in design ability of the architecture students, such as reflection in practice, solution orientation, cooperative activity, process orientation, and using the learned knowledge, can be improved.

10. CONCLUSION

In the current paper, a scientific and accurate approach based on the conducted tests in two academic semesters was applied for the master students of architecture by integrating the education of the new structures course and architectural design workshop (1).

The research findings, interpretation, analysis, and scrutinizing the criteria and indices of the research test indicate the impact of the design-based learning of the new structures on the improvement of the ability of the architecture students. And this important issue arises when it is possible to explain new structural knowledge in a physical way by explaining an efficient model and from the beginning of the design process to be used in a fully integrated way to develop the design ability in the architectural workshop.

Based on the confirmation of the research hypothesis and pilot tests (pre-test), the following results were obtained:

1. The interaction and simultaneous relationship of architectural design and the application of new structural systems in the architectural design process can enhance the main components of skill in the ability.
2. Complete and practical knowledge of various systems and new technologies and its purposeful application from the beginning of the design process (idea formation) leads to the use of innovative and creative forms in architectural design.
3. By providing a practical model, while improving the learning of new structures, it can be transferred to the design workshop and an efficient and effective model can be achieved in the purposeful teaching of architectural design and new structures.

According to the application of the research model, it is possible to develop and present an integrity and interface model in Iranian schools of architecture.

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