Application of Constructivist Educational Theory in providing Tacit Knowledge and Pedagogical Efficacy in Architectural Design Education: A Case Study of an Architecture school in Iran

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Abstract: Beginning with general debates about the character of pedagogy in architectural design studios, and the role of constructivist educational theory and tacit knowledge in efficacious learning and teaching, this article makes some predictions about the interrelationship between these processes. These predictions are then tested by conducting an empirical research at one of the early design studios of architecture education devoted to residential design, in the department of art and architecture at Kerman Azad University in Iran. These tests have shown significant differences between the design performance of students who have been subjected to constructivist educational theory in their design process, and those who encountered other pedagogical approaches. This paper uses these findings to confirm that applying constructivist educational theory in the design studio leads to an increase in tacit knowledge, the kind of knowledge that is required among designers, as design is related to a skill-based domain dealing more with knowing how to complete tasks than of mere reliance on knowing facts. In this article, it is argued that if such educational strategy gains currency in schools of architecture, the outcome will be a positive experience of pedagogical efficacy through supporting lifelong learning. This efficacy, when woven with tacit knowledge, can create architects that are more dependent on their own critical thinking abilities, more interrelated to communities of people, and more responsive to their feedbacks, which in turn allows them to be more realistic in their endeavors.

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1. Introduction

Debates about appropriate methods for architectural design education that have recently surfaced in architecture schools suggest new ideas regarding the nature of architectural design education which deserve to be explored theoretically and empirically.

This study uses experiences from the design studio and constructivist educational theory to propose a new perspective for architectural design education. It claims that the instructor's constructivist approach in the design studio encourages the acquisition of tacit knowledge rather than explicit knowledge. This is supported by an empirical research conducted at the end of the paper. Thus, the article consists of two main parts: Part one deals with theoretical debates about architecture design education, constructivist educational theory and the role of tacit knowledge in learning. Part two concerns an empirical research conducted in a real design studio in order to examine the relationship between the application of constructivist educational theory and the formation of tacit knowledge for architecture students. Based on this, the aim of the paper is to illustrate how one might integrate constructivist educational theory with the acquisition of tacit knowledge in design pedagogy.

1.1 Theoretical Perspective

A review of literature dealing with the architectural design process and education will be presented first, succeeded by a discussion of the tacit domain of knowledge. The review will continue with the theoretical basis of constructivism theory, which is our pedagogical framework. After these two stages, the article's instructional framework for constructivist design education will be introduced.

1.1.1 Architectural design education

Until recently, design was defined merely as an uncontrolled creative turn into the unconscious. In the past, architecture dealt with creating specific works of art on specific sites, where the method of design was intuitive and relied heavily upon the talent of the individual designer (Salama 1995). In more recent years, design has come to be considered a more conscious activity, as 'the first step taken by researchers was to look into the process of design and build up control mechanisms over the design process' (Uluog-lu 2000, 34). Hence, systematic design methods were discussed and applied by designers. In this respect, debates on design seemed 'to change from product-orientedness to process-orientedness, and finally to cognitive processes of the designer based on design knowledge' (Uluog-lu 2000, 34).

In response to this approach, many studies in the last three decades of 20[th] century were devoted to the role of knowledge in the architectural design process (Uluog-lu 2000). The common factor observed in most of these studies was that the process of design requires the skillful activity of the body (hands) and intuitive feelings of the soul, as well as the rational activity of the mind (Schon 1981). In a study of architecture design, Uluoglu (2000) claims that, as designing is not simply an act of doing, it requires a controlled conduct of a general course made up of knowledge. Designing is not merely an activity based on certain skills, to be taught by instruction, and thus the inclination toward knowledge-based design processes has caught the attention of design education as well (Uluoglu 2000).

Despite all considerations given to knowledge-based process of design in architectural literature and education, the inadequate amount of knowledge applied in the practice of professional and educational design processes has been the focus of many criticisms in the last three decades (Salama 1995, Uluog-lu 2000). That is because, as Robinson (1986) cites, 'Educational institutions are apparently turning away from the pragmatic, rational approach, towards an approach based more in art than science' (67). Due to this current situation, a growing dissatisfaction with design education appears to be the main concern of researchers and academicians who have voiced the notion that the education of future architects should be knowledge-based (Banham 1981; Boyle 1977; Wolfe 1981; Juhasz 1981; Bowser 1983; Mayo 1985 & 1991; Ozkan 1986; Cuff 1991; Schon 1983, 1985 & 1988; Gutman 1968, 1987 & 1988; Gerlenter 1988; Dagenhart 1993; Watson 1993; Weber 1994 and many others). A review of the above studies demonstrates that most criticisms of design education are concerned with forming analogies between the artistic and instructor-centered approach to architecture in the current design studios, with the actual way of developing architecture in professional practice. The criticism claims that in the current educational system, instructors are not required to position themselves on what Stevens (1998) calls the continuum from workaday practice to activity in a sphere of symbolism. Instruction is therefore based on the preferred behavior of instructors and those who select them for the job (Stevens 1998). Hence upon entering the workforce, the graduates will be armed with their instructors' architectural interests and tastes, but unable to create by themselves. This criticism accentuates the point that, although architectural design is a broadly knowledge-based activity regarding all aspects of human life, the essence of architectural design education follows ready-made principles and rules developed in the past, and not equipped to confront future architects with the environmental needs of contemporary societies.

Analyzing this criticism, which considers design studio instruction, confirms that the current design studio is greatly influenced by the ***Beaux-Arts*** (Salama 1995) According to Balfour (1981), Beinart (1981), Bostick ***& Pettena*** (1985) and McCommons (1989 & 1994), studio instruction has essentially remained unchanged since the establishment of the ***Beaux-Arts*** approach. This approach has placed emphasis on the formal aspects of architecture with little concern for socio-cultural issues (Salama 1995). According to Papanek (1971), designers following this conventional approach are likely to distance themselves from the real world and real human problems, and so do not touch the depth of human experience and needs.

The strength and assurance of the ***Beaux-Arts*** approach was in leading toward the creation of architecture and design programs in many developing countries in the early 20th century (Van Zanten 1977, 115). Hence, all the numerous criticism that has questioned this educational model is relevant to all the programs that adopted the same system of design education. Iran, the focus of this article's empirical study, has also followed the ***Beaux-Arts*** pattern in architectural education. The years between the two world wars were crucial for Iran's architecture profession, as it witnessed a complete transformation in the organization of the profession. At that time many Iranian students went abroad to study architecture, and many to Paris. As a result, the ***Beaux-Arts*** model of architectural education came to be favored. The graduates who had experienced the ***Beaux-Arts*** system became the founders of academic education of architecture in Iran. As a result, the first schools of architecture in Tehran, like other Middle Eastern countries, focused on ***Beaux-Arts*** based curricula. (Etesam 2004, Bavar 2006)

The traditional master/apprentice ***Beaux-Arts*** model of studio instruction involves a heavy dependence on the instructor for decision-making and mere reliance on manipulation of formal configurations (Salama 1995). This traditional model encourages a studio environment that inhibits students' thinking capabilities and declines the general level of design. It actually establishes a lack of knowledge, promoting students to look to the instructor for design ideas and wait for his or her approval before making design decisions—a custom found in most studio teaching practices worldwide (Salama 1995). This lack of knowledge, which was defined by Salama (1995) as one of the factors that affect and limit the capabilities of architects should be abolished from design education.

Ochner (2000) describes the traditional model of studio instruction as a setting through which some studio instructors pass along design solutions to their students in order to enable them to produce projects at a high degree of completeness that meet their expectations. Indeed, this is likely inevitable in any design studio to some extent, but too much can be destructive for the students's later professional career. Continuing this debate, Ochner (2000) asks a fundamental question that challenges the educational goal of the traditional model of studio instruction: 'The results in one studio may look good, but what of the students' development over time?' (Ochner 2000, 198). In such instruction, the students will always depend on an external source for making design decisions. Psychoanalyst Fred Pine (1990) has written:

> If one were stranded on a desert isle, it would probably be better to find there a set of tools than, say, a finished house. The house would indeed provide shelter …, but the tools could each be used flexibly in innumerable ways—including the building of a house. *(*20)

Design studios should provide students with tools to solve problems, not with products and solutions to specific challenges that are likely to change over the course of the students' careers. Reviewing different studies on architecture education indicates that the current model of teaching and learning is not used because it is the 'right way,' but because the method has worked for such a long time (Farrington 1999). This dissatisfaction has led many researchers to study the deeper aspects of design education (Ochner 2000). Hence, as a reaction to this situation, several revolutionary concepts have been developed by different design instructors in an attempt to respond to the new demands of the profession and the changing role of the architect in society. But as such struggles are still in the early stages, and because there are few studies on the instructional framework appropriate for design education, the *Beaux-Arts* approach is still current in design education all over the world (Salama 1995).

Many researchers and academicians have expressed a concern that the education of future architects must reinforce an independent ability of design decision-making (Schon 1983). The ability to support such decisions throughout the student's professional career could be acquired through conversion of the superficial type of learning to an in-depth learning that comes with endogenous knowledge construction (Etesam, 2008)). While the literature of architectural education may be silent on how such lifelong learning can be created, lessons can be drawn from the experience of educationalists in developing instructional models. This article is devoted to such an approach.

1.1.2. Lifelong learning through tacit knowledge acquisition

Professional knowledge acquisition and promoting lifelong professional learning are some of the most important aims defined for education in various studies (Facione & Facione 1994, OCED 1996, Tiwari, Lai, So & Yuen 2006). As Facione & Facione (1994) declare, such emphasis on lifelong learning is due to the 21st century's 'global, social, economic, educational and environmental challenges, which does not demand the teaching of soon-to-be obsolete facts' (1). Education has been faced with new challenges in the 21st century, including the knowledge concept, its management and the development of a workforce with the skills necessary to support professional careers (Grant, 2000). One such approach to this has been the development of lifelong learning policies (OCED, 1996). Lifelong learning, which is defined as 'continuous professional development' or CPD by Chisholm and Holifield (2004, 242), facilitates the efficacy of the working population by continuously up-skilling them forever. Such attitudes toward education can generate self-reliance among students, which is desirable in many fields of education, including architecture. Based on such studies one can argue that pedagogical efficacy is related to acquisition and promoting lifelong professional learning at all levels of education, and in architectural design education as well. Thus, how education reacts to and develops knowledge for lifelong learning is now a critical dimension to be addressed. Hence, the critical to ask is how professional knowledge acquisition can lead to lifelong learning. To answer this question, one should enter the domain of different types of ideas regarding knowledge acquisition.

Treatises and textbooks on knowledge management distinguish explicit knowledge from tacit knowledge as two major types (Polanyi 1996; Rumizen 2002). While explicit knowledge includes that knowledge which can be stated and is in that sense objective, tacit knowledge can not necessarily be explicitly stated or written down, and tends to be more subjective. The distinction between tacit knowledge and explicit knowledge has been described in terms of `knowing-how' and 'knowing-that,' respectively (Ryle 1949/1984). Tacit knowledge includes judgment, experience, insights, rules of thumb, and intuition, and its retrieval depends upon motivation, attitudes, values, and the social context. Professionals and other experts generally perform their practice primarily on the basis of tacit knowledge. Thoughtful writing, group work on complex problems and interactions with multifaceted applications depends heavily on tacit knowledge. Chisholm and Holifield (2004) review the role of tacit knowledge in organizations with an emphasis on its role and importance for lifelong learning. The reason why tacit knowledge best enables lifelong learning lies in its nature, the personal knowledge resident within the mind, behavior and perceptions of individuals (Casonato & Harris 1999, Rumizen 2002) Based on all these facts, one could argue that if the knowledge acquired through the learning process becomes tacit knowledge, it may be retained in the learner's mind for life. Hence a preliminary answer to the question of the way through which professional knowledge acquisition may lead to lifelong learning would deal with the type of acquired knowledge. Thus, while tacit knowledge may be needed to facilitate the acquisition of skills, it can be argued that it no longer becomes necessary for the practice of those skills once the person becomes an expert in exercising them (Polanyi 1958 & 1974).

Current research in tacit knowledge is motivated by the acceptance that much of what underpins a successful career in an organization is directly associated with implicit knowledge and learning (Chisholm & Holifield 2004). Thus, tacit knowledge plays a major role in learning and teaching when complex problem solving is involved.
Architectural design education is one of the complex domains of problem solving. As architecture is a science with roots in the field of art to a great extent, the kind of knowledge that its design process deals with is not entirely explicit. Architecture's relation to the world of art along with the skill-based character of design, reveal its relevance to the `knowing-how' domain of knowledge, thus architectural designing skills could be defined as tacit knowledge. In this respect, architectural design, which belongs to the `knowing how' domain of knowledge, is associated with an artist who designs and makes judgments without always explicitly reflecting on the principles of the rules involved. Of course as architectural design also relates to the field of science as well as art, the skills used by designers are based on consciously-accessible knowledge that can be articulated. It can be argued, however, that while this knowledge may be needed to facilitate the acquisition of skills, it no longer becomes necessary for the practice of those skills once the person becomes an expert in exercising them (Polanyi 1958 & 1974). Based on this discussion, the skills needed in the process of architectural design have their roots in the tacit domain of knowledge. Thus, the acquisition of tacit knowledge in architectural design education can be defined as pedagogical efficacy.

The question then arises as to which educational approaches are be able to promote the acquisition of tacit knowledge and lifelong learning. In order to move toward the answer, this paper will review the studies, although few, that have been conducted on this topic in the following section.

1.1.3. Constructivist Education as a key to Lifelong Learning and Tacit Knowledge Acquisition

Since little research has been completed on tacit knowledge production (Koskinen 2003), it is difficult to propose an exact response to the question seeking a proper educational approach that would be able to promote tacit knowledge and lifelong acquisition. This problem with tacit knowledge is essentially due to its implicit nature making it difficult to scientifically discuss and explain explicit knowledge. While the articulate manner of explicit knowledge makes it possible to be acquired through formal education, writings and books, tacit knowledge when transferred by sight, 'is either acquired through an "intimate" relationship between a "master" and an "apprentice," or through learned experience over time' (Busch 2004, 17).

Despite the dilemmas that exist over the acquisition of tacit knowledge, and despite the silence of educational literature, a profound scrutiny of the available text exposes some points about the implicitly recommended approaches to creating tacit knowledge. One such suggested approach is the study by Chisholm and Holifield (2004) regarding tacit knowledge and professional development. The authors, after reviewing the role of tacit knowledge in companies and its importance for lifelong learning, conclude by demonstrating that a work-based learning model is the most effective way to deliver lifelong learning supported by the emphasis on tacit knowledge acquisition. The work-based learning model can be associated with lifelong learning policies and knowledge construction by individuals. One of the educational approaches supporting the work-based learning model as defined in their study is constructivist educational theory.

Constructivism is based on the doctrine that learning takes place in contexts, and that learners form or construct much of their learning as a function of their experiences in various situations (Schunk 2000). More recently, researchers (e.g. Lave 1990; Saxe, Guberman & Gearheart 1987) have presented more qualitative documentation of learning in context. Hence, this approach can be simulated to the work-based model of learning, which was previously introduced as a key to tacit knowledge and lifelong learning. This tendency of work-based learning and constructivist educational theory to provide tacit knowledge and lifelong learning has been expressed implicitly in other studies as well (von Krogh & Roos 1996, von Krogh, Ichijo & Nonaka 2000, Atherton 2002, Burns 2001, Chisholm 2002, Saint-Onge 1996). A review of the above literature on tacit knowledge may lead to the conclusion that constructivist educational theory is one of the key approaches to acquiring tacit knowledge and lifelong learning, as it is consequent in both educational and professional environments. Before coming to the specific focus of the paper, which addresses architecture education and acquisition of tacit design knowledge, an analytical discussion on constructivist educational theory in general is presented.

1.1.4. An Overview of Constructivism Theory

Previous discussions presented on tacit knowledge acquisition and lifelong learning imply that constructivist views of learning and education could help to achieve such knowledge. Constructivism, derived mainly from the works of Piaget (1970), Bruner (1962, 1979), Vygotsky (1962, 1978), and Papert (1980, 1983), is both a philosophical and psychological approach (Schunk 2000). Although the roots of constructivism are most often attributed to the work of Jean Piaget, constructivist doctrines emerged much earlier in history, as seen in the writings of Giambattista Vico, who declared in 1710 that 'the human mind can know only what the human mind has made' (von Glasersfeld 1995, 21). The meaning of constructivism varies according to perspective and position. Within educational contexts there are philosophical meanings of constructivism (Mathews 1998), as well as personal constructivism as described by Piaget (1967), social constructivism outlined by Vygtosky (1978), and radical constructivism advocated by von Glasersfeld (1995).

Educational constructivism is clearly defined through Piaget's focus on the active role of the individual in learning. Based on this focus, constructivist views assert that learning is the active process of constructing rather than passively acquiring knowledge. Hence, instruction is the process of supporting the knowledge constructed by the learners rather than the mere communication of previously-learned knowledge (Duffy & Cunningham 1996; Honebein, Duffy & Fishman 1993; Jonassen 1999). The Main features of constructivism as derived from the constructive-interpretive literature are presented in Table 1.

von Glasersfeld (1995) emphasizes the outcome of constructivism education and defines knowledge as having no alternative except construction in the mind of learners. Through this way of teaching, students gain a stronger grasp of complex ideas (Applefield, Huber & Moallem 2001). Hence, one of the merits of constructivism is that it will accentuate the goal of achieving depth of learning rather than breath of learning (Brooks & Brooks, 1993), which may reduce the probability of forgetting the learnt material. This is by itself an important educational goal. This learning approach, which 'involves learning with depth' (Applefield, Huber & Moallem 2001, 29), is also defined by Lock (1947) as the ability of mind to 'put together those ideas it has, and make new complex one' (65). Considering this and the fact that the information received by individuals is not convertible to knowledge until they understand what it is, one could argue that the new complex made through the constructivist view relates to the field of knowledge, not to the field of raw data and information (Busch 2004). Therefore, as heavy emphasis of traditional education on information and its recall causes inevitable results of quickly forgetting (Applefield, Huber & Moallem 2001), the constructivist focus on knowledge instead of information can be defined as another educational merit.

The great contribution of constructivism to education may be through the shift in emphasis from knowledge as a product to knowing as a process (Jonassen 1991). This property of constructivism is capable of causing a lasting and meaningful change in the structure of formal education.

In the final analysis, it becomes of great significance that the application of constructivism to instructional design has certain advantages, including acquisition of deeper levels of understanding, providing more meaningful learning outcomes through more meaningful learning contexts, more independent problem-solving capabilities, more flexibility in both design and instruction activities, and supporting the learners with an ability to apply their learning in non-academic contexts (Karagiorgi & Symeou 2005, Russell & Schneiderheinze 2005). Despite the merits cited for constructivism, the translation of constructivism into practice constitutes an important challenge for instructional designers (Karagiorgi & Symeou 2005). An overview of some efforts conducted to move towards pragmatic constructivism is presented below.

Table 1. Family Characteristics of Constructivist Instructional Design

1	**The process Is Recursive, Non-linear, and Sometimes Chaotic:** Development is recursive, iterative and also non-linear. There is no required beginning task that must be completed before all others. Some problems, improvements, or changes will only be discovered in the context of use. It Plan for false starts and redesigns as-well as revisions.
2	**Planning Is Organic, Developmental, Reflective, and Collaborative:** Begin with a vague plan and fill in the details as you progress. "Vision and strategic planning come later. Premature visions and planning can blind" (Fullan, 1993). Development should be collaborative. Vision may emerge over the process of development. It cannot be "established" at the beginning. "Today, ... If people don't have their own vision, all they can do is 'sign up' for someone else's." (Senge, 1990, 206-211)
3	**Objectives Emerge from Design and Development Work:** Objectives do not guide development. Instead, during the process of development, objectives emerge and gradually become clearer.
4	**General ID Experts Don't Exist:** General ID specialists, who can work with subject matter experts, are a myth. You must understand the "game' being played before you can help develop instruction.
5	**Instruction Emphasizes Learning in Meaningful Contexts:** The Goal Is Personal Understanding Within Meaningful Contexts. Standard direct-instruction approaches that focus on teaching content outside a meaningful context often result in "inert' knowledge. The instructional emphasis should be on developing understanding in context. This approach favors instructional approaches that pose problems and provide students with access to knowledge needed to solve the problems.
6	**Formative Evaluation Is Critical:** Invest the most assessment effort in the formative evaluations because they are the ones that provide feedback you can use to improve the product. Summative evaluation are not useful.
7	**Subjective Data May Be the Most Valuable** : Many important goals and objectives cannot be adequately assessed with multiple choice exams, and exclusive reliance on such measures often limits the vision and value of instruction. during the instructional design process, there are many points where informal or qualitative approaches, such as interviews, observations, user logs, focus groups, expert critiques, and verbal student feedback, can be much more valuable than a data from a 10 item, questionnaire.

1.1.5. Instructional Models for Constructivist Education

Despite the theories presented by constructivist experts such as Duffy, Lowyck & Jonassen (1993), Jonassen (1999), and Wilson (1996), few studies have implemented constructivist strategies and confirmed their effectiveness. The reason for this is that most instructional designers do not unconditionally embrace this new epistemology, as there are many areas of conflict (Karagiorgi & Symeou 2005). Educational models subscribing to constructivism have described its impact on instructional design in general (Lebow 1993; Ertmer & Newby 1993). Most such generally proposed constructivist instructional models do not prescribe a design procedure or elaborate on the precise teaching style of each task. Instead they describe the design process in terms of general principles and guidelines. Some of these models include chaos theory (You 1994); recursive and reflective design and development, or R2D2 (Willis 1995), layers of negotiation (Cennamo & Chung 1996); the 5E model—engage, explore, explain, elaborate, and evaluate (Bybee 1997), initiating – constructing – utilizing (Stephens & Brown 2000); and the 7E Model—elicit, engage, explore, explain, elaborate, evaluate and extend (Eisenkraft 2003).

In addition to these general models, some important attempts toward defining the relationship between theory and practice have been made as well. As the constructivist approach is entirely reliable on an investigative approach, its main beliefs are expressed through investigative activities, cooperative learning and a variety of hands-on experiments (Applefield, Huber & Moallem 2001). In addition to positive outcomes of constructivism in science (Neale, Smith, & Johnson 1990), similar successes have been reported for this approach in reading, writing and language arts instruction (Duffy & Roehler 1986, Bereiter & Scardamalia 1987). Russell and Schneiderheinze (2005) conduct a study on the theoretical and practical applications of constructivist learning principles in the United States. The process was an online collaboration aiming to develop higher-order thinking responses among students. For the purposes of this study, the researchers identify important concepts based on a constructivist theoretical framework that contributes to the design of a constructivist instruction. The concepts used in this study include ‘scaffolding and mediation (Vygotsky, 1986; Wertsch, 1998), goal-directed, meaningful context and inquiry (Lave & Wenger, 1991), and collaboration (Salomon, 1993)’ (Russell and Schneiderheinze 2005, 9). The potential and limitations of translating constructivism into instructional design are discussed in another study by Karagiorgi and Symeou (2005). In this study, use of cognitive and technology tools is recommended to develop constructivist methods.

An example of how tools can develop practical constructivism is presented in a model by Jonassen (1999) aimed at designing constructivist learning environments. Through the model, learners are aided in understanding the problems and finding solutions through related information resources. Recommended tools in this model include 'task representation tools (visualisation tools), static and dynamic knowledge modeling tools, performance support tools and information-gathering tools. In addition, conversation and collaboration tools are helpful to construct meaning of the problem' (Karagiorgi & Symeou 2005, 23). Hence, it can be argued in general that technology-related environments, in addition to virtual reality and real world simulations, are alternatives to making constructivist approaches more practical by providing more learner-centered opportunities and by offering multiple representations of reality (Wilson 1997, Mergel 1998, Cey 2001, Karagiorgi and Symeou 2005). Despite the general recommendations cited in the reviewed literature regarding constructivist practical instruction, no specific constructivist instructional model exists that is able to fit all fields of education. Therefore it is necessary for specialist educators in each individual field of education to develop specific proper models of their own, according to general guidelines of constructivist educational theory. To achieve such a goal in architectural design education, the few accomplished studies relevant to this field will be reviewed in the following section.

1.1.6. Implications for Constructivist Architectural Design Education

As discussed in the previous section, a number of theorists have approached the ways in which constructivist values influence instructional design, and have proposed several generalized principles of the constructivist instructional model (see for example Lebow, 1993; Jonassen, 1994; Willis, 1995). However a review of the relevant literature reveals little research on how general constructivist principles impact particular educational fields such as architectural design. However, in recent years, some efforts have been conducted in the field of design education based on the constructivist learning approach. Most of the studies in this field relate to the recent developments in information and communication technologies. In a study by Al-Ali (2007), some VDS (Virtual Design Studio) pedagogical techniques, with debates on their relevance to constructivism, are proposed. Some of these techniques cited by Al-Ali (2007) include project-based learning, group discussion, critical thinking and simulated real-world imitation. In a study by Gul, Gu and Williams (2008), 3D virtual world technologies, which support synchronized design communication and real-time 3D modeling' (1), are introduced to make a significant contribution to design education as a constructivist learning environment. This study discusses how some virtual computer-based programs facilitate constructivist learning by providing the affordances of modeling, communication and computational features of 3D virtual worlds. In another study regarding constructivist architecture education, Wang (2009) seeks to explain how the expanded use of computer-aided design in the professional education of architects is related to constructivist education. Although the study holds the promise of introducing a constructivist model of architecture education, it was unable to fill the large gap between constructivism theoretical potential for education and its actual performance in a design studio, primarily due to its focuses on ICT techniques as the only methods of constructivist education.

In addition to the reviewed studies that support technology-related tools as a potential to facilitate constructivist learning activities, a review of the basis of computer-based education, which appears through Anderson's cognitive theory (Anderson 1983 & 1976), reveals similar relationships between computer-based education and constructivism. Anderson's theory for computer-based education includes the following principals:

'1. Identifying the goal structure of the problem space,
2. Providing instruction in the context of problem-solving,
3. Providing immediate feedback on errors,
4. Minimizing working memory load,
5. Adjusting the "grain size" of instruction with learning to account for the knowledge compilation process, and
6. Enabling the student to approach the target skill by successive approximation' (Anderson 1983 & 1976, in Gül et al. 2008, 580).

While the first three principles defined by Anderson (1983, 1976) express the merits of computer-based education, the last three stand precisely on the principles cited for constructivist learning and education. In the fourth approach, which relies on an understanding of how students interact with knowledge, the assumption is that knowledge is constructed by the students themselves, not delivered by the instructor (Winn, 1993). This approach is the same as accepted constructivism theory, as in the constructivist view, knowledge is constructed, not transmitted, and the students actively learn (Jonassen, 1999). In the fifth and sixth approach, it is expected that students are given the opportunity for exploration and manipulation within the environment, as well as opportunities for discourse between them to enhance learning (Dickey, 2007). In learning as a constructivist activity, as well, the role of the teacher is only 'to help and guide the student in the conceptual organization of certain areas of experience' (Glasersfeld 1983, 23).

Based on the above discussion, it can be argued that virtual models offer constructivist learning environments and can enhance learning by providing opportunities for exploration, facing students with the consequences of their design decisions in a real context, and providing opportunities for more critical discourse between students and teachers based on the designed spaces now visible thanks to 3D modeling tools. Hence, the use of 3D modeling and computer-aided design can be employed as a design teaching approach, which includes the facilitation of constructivist learning and tacit knowledge acquisition as its subsequent.

1.1.7. Constructivist Design Process and its Relevance to Computer-Aided Design

Before arriving at the empirical section of the study, it is necessary to achieve a practical framework for architectural design education based on constructivist educational theory. For the purposes of this article, reference is made to the relevance of computer-aided design in constructivism in terms of the three major stages of architecture design process, as defined by Lang (1987)—the information gathering stage (preparation for design), the design development stage (establishing the design solutions), and the evaluation stage (choosing). These three dimensions are used here as poles for further discussion.

1.1.7.1. Stage 1: Information Gathering (preparation for design**)**

Throughout this phase of the design process, students gather an abundance of information relevant to different aspects of the design problem. In the constructivist approach and in the content of required information, this stage cannot be pre-specified (Karagiorgi & Symeou 2005, Gül et al. 2008). Constructivist instruction of design avoids the breakdown of context into component parts, as traditional design instruction does, and is instead in favor of environments in which design knowledge and solution can emerge naturally. Designers (here, students) in this stage distinguish between various needs and requirements of the given design problem, which their proposing design solution aims to fulfill. As design problems have no absolute solution, the task in this stage is one of providing a rich context within which specific objectives of understanding the environment, for proposing the best design solution, can emerge (Al-Ali 2007). The goal, for instance, is not to gather information on different forms of traditional architecture to be imitated, but to make students understand the context and environment in which a specific form of architecture has emerged, and the requirements it must have fulfilled.

To achieve such goals, designers (here, students) refer to different sources in order to understand concepts important to the design of the problem. This in-depth research enables students to identify design tasks, clients, and legal constraints. As students work to develop the requirements of a design problem, the teacher helps the students by providing them with the opportunity to adapt the acquired information to their needs, to make choices with which to direct their learning, and to construct their own understanding of the information. This constructivist approach aims to help students develop useful knowledge rather than inert knowledge (Russell & Schneiderheinze 2005, Al-Ali 2007). In this stage of the design process, students require access to information such as text documents, videos, sound files and graphics to begin formulating meaning about the problem, as well as related cases to represent the complexity of the problem from multiple perspectives. The teacher can help to establish the meaningful context by providing students with opportunities to gather information and question the relevance of that information to their community and the problem. Consequently, the teacher can provide opportunities for students to analyze case studies (Shulman 1992) about other projects related to design problem-solving in order to enrich the context for students to apply expertise and identify interrelationships among those areas of expertise.

The application of computer-aided technologies into this stage of the design process offers significant potential for design schools, through their capacity of advancing research and development, to prepare students for designing in the next stage of the design process. Computer-aided design tools also support the so-called library-based design method which comprises a set of objects, materials, textures and light sources provided by the object library of the design platform (Gül et al. 2008). Based on the above discussion, technology application can extract more meaning from the design problem and can be helpful in supporting the research in the design studio. It is further able to foster the development of a design solution in the following step of the design process.

1.1.7.2. Stage 2 + Stage 3: Design Development + Evaluation

Based on literature reviewed above regarding architectural design education (see for example Salama 1995), it could be cited that in the traditional instruction of design, which is teacher-centered and teacher-directed, the stage of design development stands completely apart from the stage of design evaluation. This is primarily due to the fact that these two tasks are expected to be carried out by separate individuals—the role of te students is only to propose alternatives and design solutions, while that of the instructor is as the main center of instruction, with the role in evaluating and judging the students' designs. But these two stages, in the constructivist approach of design education, are interwoven. Since constructivists points to student-centered, student-directed and collaborative environments based on intera*ctive* learning, both stages should be accomplished through students' self-relied activities. Students may evaluate their design solutions in terms of whether they do what they claim to do (Spiro et al. 1991b). The students' ability to promote insight into alternative perspectives is an important element of evaluation, and is related to the development of their critical thinking skills and self-reflective processes (Karagiorgi & Symeou 2005). Such a learning environment requires an abundance of tools to confront students with opportunities to experience the critical thinking inherent in design education. Computer-aided design tools and 3D-modeling tools can be helpful in providing such an environment (Al-Ali 2007). As computer-aided design tools can support different viewpoints, such as first-person and third-person, they offer many possibilities for understanding the spatial arrangement of the objects and developing the student's spatial abilities (Gül et al. 2008). Thus, to modify a design, the students are able to rely heavily on their own judgment of the finished proposed design, which is visible now through the aids of technology.

From these studies it is clear that designing with the help of 3D virtual worlds encourages immediate and detailed design decisions for students. While they decide on a particular concept or design alternative, both its construction and testing occurs simultaneously. Hence this method has the potential to facilitate self-reliance among students in the design process, due to the faact that computer-aided design tools allow learners to develop, compare, and understand multiple perspectives of an issue with the goal of achieving the rigorous process of reflective thinking, multiple perspectives, developing and evaluating the arguments by self-mentoring to guide learning (Bednar et al., 1992, Gül et al. 2008). As a result, students are capable of experiencing the evaluation stage of the design process along with the development of design. By applying computer-aided design tools, teachers can plan a constructivist instruction in architectural design education that goes beyond routine learning toward meaningful learning that is more likely to lead to deeper and longer-lasting understandings.

1.2. Empirical Study

According to the discourses presented in the theoretical section of this article, it is assumed that the application of constructivist educational theory in architectural design instruction, which deals with skills and knowledge of the 'how' questions (Busch 2004), can lead to tacit knowledge acquisition. If so, we can, and should, expect the studio to be an environment in which such knowledge is transferred to students in various ways.

As discussed above, lifelong learning is one of the merits of focusing on tacit knowledge acquisition. Based on this property of tacit knowledge, the length of time that the acquired knowledge is retained in the mind is considered one of the indicators of tacit knowledge existence

2. Material and Methods

This section examines the students' tacit knowledge acquisition and the effect of applying constructivism educational theory in architectural design instruction. As discussed above, tacit knowledge is closely related to the learner's potential for retaining the learnt knowledge over a long period of time. The more tacit knowledge one acquires through the learning process, the longer he or she is likely to retain it. The project was an experimental research study based on an analysis of students' design performance in accordance with the studio instruction in 'priori and posteriori' stages (Groat & Wang 2002). The goal was to gain a multilayered outcome of the students' designs, as they were treated with constructivist instruction in the design studio.

In this study the experimental design with pre- and post-tests is applied. The sample was comprised of second-year architecture students from the Department of Architecture at Islamic Azad University - Kerman Branch, in the second semester of the 2009-2010 academic year. They had taken the architectural design course, dedicated to the design of a one-family residential house in a pre-determined site. The size of the sample group was 32 students; 9 male and 23 female. Sixteen students were considered the control group, and 16 students were considered the experimental group. In order to reduce the impact of different variants in the instruction model, the two groups were instructed by the same teacher. In addition, to reduce the impact of varied learning potentials among the students, the students of each group were selected in equal ratios based on their previous grades. The experimental group encountered the constructivist approach during the instructional design process, while the control group was instructed using the traditional method of direct instruction. Ultimately, acquisition of tacit knowledge in both groups was measured by the students' capability to retain the learnt knowledge of design after nine months. The second semester of the academic year in Iran begins in February and finishes in June, and the following semester begins after a three-month summer vacation. The project spanned a nine-month period. The long break between the two semesters provided an opportunity to check the students' capability of retaining knowledge. In order to maintain the natural condition of the two design studios, and to avoid role playing, the students were not aware of the goals behind this difference in their instruction. At the beginning of the semester, the basic design knowledge of all 32 students was determined by asking them to take part in designing a one-family residential flat for 4 family members in a suburban site of about 100 square meters in the span of eight hours. The site presented to the students was a real-world existing site that students can walk through to explore the site's real limitations and potential. One of the problems of the site was that the carpentry workshop was located on the north side with an abundance of disturbing sounds. Each student's sketch was kept for further comparison and analysis. This exercise is called "sketch number one" in the following discussions. After this stage, the students were divided into experimental and control groups. The 16 students who comprised the experimental group encountered the constructivism method during their instructional process through the three-month semester. The other group, as the control, was instructed via methods other than constructivism. At the end of the term, both groups had arrived to satisfactory results; hence all students passed the architectural design course one. An example of the way through which the students in each group were instructed regarding one special aspect of residential design is presented below.

Example 1- Unsuitable Space Adjacency: not considering sound disturbing zones in a site

It was obvious that because of the noise condition, the north side of the site was not a proper location for resting zones, for example, bedrooms, of a residential unit. Some of the students in both the control group and the experimental group, however, did not pay attention to this aspect at the beginning of the design process, and placed the bedrooms in this zone. In the instructional process, the instructor behaved in two different ways regarding the students of the experimental and control group. The designs of the control group members, confronted with the traditional direct instruction, were corrected directly by the instructor; they were told that the design was not adequate, and that "the bedrooms should be placed in this quiet zone, on the south side." But the experimental group students were just asked to go to the site and try to rest, study or spend time in the specific location they had proposed for the bedrooms. They were asked to record the sounds and put the recorded sound to the 3D modeling simulation they had created of the proposed bedroom space of their designs. They were then asked to show this simulation with the relevant sound on, to other students, friends, relatives and others to observe their responses to such an environment.

In this example, while the control group was confronted with explicit, codified knowledge by being told that 'the bedrooms should be placed in a quiet zone,' the experimental group was confronted with another method.

The experimental students succeeded in experiencing the impact of placing the bedrooms in an unsuitable location and had constructed the above rule by themselves. They did not receive an explicit kind of knowledge about this subject, but instead acquired the experience and skill from reliance on their own abilities and observations. Three months later, after the summer vacation, all 32 students began the following semester and took the second architectural design course. During the first week of the new semester, the 32 students were asked to take part in "sketch number two," an eight-hour design struggle with the same subject as "sketch number one." In the second sketch exercise, however, the site location of the desired residential house and its number of family members differed. In this sketch a carpentry workshop was located at the eastern side of the new site, and a freeway was located at the southern edge. The natural lightening potential of the site was also limited to the east and south, preventing windows in the west and north. They were asked to use natural light for all spaces. Each student's sketch was collected to be compared with his or her first sketch. An example of this stage is presented below.

Example 2- Unsuitable Space Adjacency: not considering sound disturbing zones in a site

The students of the control group did not place the bedrooms next to the carpentry, but instead placed them on the southern edge next to the freeway in *order to use the light from the south. Because of their prior experience in being prohibited from placing bedrooms next to the carpentry workshop, they reclined the disturbing sound of the freeway instead (for example Student C.8). Some of them also placed the bedrooms in the north or west sides of the site ignoring the criterion of benefiting from light. Students of the experimental group avoided disturbing sounds from both the freeway and the carpentry workshop, as they had already experienced the simulated space with harmful sounds. As they were obliged to use natural light under these conditions, most came to new solutions. Student E.11, for example, placed an internal yard in the residential unit to solve the light problem, and then placed the bedrooms on the west and north of the site.*

After preparing this data, a comparative analysis between each student's two sketches, over a nine-month period, was conducted in order to detect the effect of using constructivism educational theory in design education for creating tacit knowledge. Emerging improvement between the two sketches for those who encountered the constructivist educational method demonstrates that the student was able to retain the learnt knowledge for a long period of time, and created a kind of tacit knowledge. If the location of the student's bedrooms remained unchanged in their design capability, it would prove that the constructivist educational method had no effect on students' tacit knowledge acquisition.

3. Results

The analysis of the results began with an in-depth analysis of each student's sketches. At this stage, an initial list of the most repeated mistakes was compiled. After reviewing the initial list of mistakes and their relationships, connections, similarities and differences, 14 categories of major mistakes emerged. Tables 2, 3 and 4 contain a summary of the categories of mistakes. The most important mistakes that the students committed while designing sketch number one are listed in Table 2. The data provided here shows that the majority of students made basic mistakes in designing the sketch.

Table 2. The most important design mistakes committed by students in sketch number one

students' mistakes in sketch No.1	**Number Total 32**	**percent**	**C:16 N:16**	**Number**	**percent**
Unsuitable orientation	31	96.8%	E	16	100%
			C	15	93.75%
Wrong circulation	28	87.5%	C	15	93.75%
			N	13	81.25%
Unacceptable lightening	26	81.2%	C	14	87. 5%
			N	12	75%
Unsuitable space adjacency	32	100%	C	16	100%
			N	16	100%
Poor organization of spaces	32	100%	C	16	100%
			N	16	100%
Poor Approach to the building	32	100%	C	16	100%
			N	16	100%
Functional problems	29	90.6%	C	15	93.75%
			N	14	87. 5%
Aesthetic ignorance	32	100%	C	16	50%
			N	16	100%
Poor composition of form	31	96.8%	C	16	100%
			N	15	93.75%
Unsuitable standards	32	100%	C	16	100%
			N	16	100%
Unsuitable spatial relations	32	100%	C	16	100%
			N	16	100%
Unsuitable separation of Private and public zones	28	87.5%	C	14	87. 5%
			N	14	87. 5%
Poor interior design	32	100%	C	16	100%
			N	16	100%
Poor providing of views	30	93.7%	C	16	100%
			N	14	87. 5%

Table 3. The most important design mistakes committed by students through their final project

students' mistakes in final project	Number Total 32	percent	C:16 N:16	Number	percent
Unsuitable orientation	1	3.12%	C	0	0
			N	1	6.25%
Wrong circulation	0	0	C	0	0
			N	0	0
Unacceptable lightening	2	6.25%	C	1	6.25%
			N	1	6.25%
Unsuitable space adjacency	1	3.12%	C	0	0
			N	1	6.25%
Poor organization of spaces	3	9.36%	C	1	6.25%
			N	2	12.5%
Poor Approach to the building	6	18.75%	C	2	12.5%
			N	4	25%
Functional problems	2	6.25%	C	0	0
			N	2	12.5%
Aesthetic ignorance	17	53.1%	C	8	50%
			N	9	56.25%
Poor composition of form	10	31.2%	C	4	25%
			N	6	37.5%
Unsuitable standards	0	0	C	0	0
			N	0	0
Unsuitable spatial relations	1	3.12%	C	1	6.25%
			N	0	0
Unsuitable separation of Private and public zones	2	6.25%	C	0	0
			N	2	12.5%
Poor interior design	23	71.8%	C	11	68.75%
			N	12	75%
Poor providing of views	8	25%	C	3	18.75%
			N	5	31.25%

Table 4. The most important design mistakes committed by students in sketch number one

Code	students' mistakes in sketch No.2	Number Total 32	Percent In whole	C:16 N:16	Number	Percent In each group
A	Unsuitable orientation	15	46.87%	C	2	12.5%
				N	13	81.25%
B	Wrong circulation	14	43.75%	C	3	18.75%
				N	11	68.75%
C	Unacceptable lightening	14	43.75%	C	4	25%
				N	10	62.5%
D	Unsuitable space adjacency	15	46.87%	C	2	12.5%
				N	13	81.25%
E	Poor organization of spaces	19	59.37%	C	5	31.25%
				N	14	87.5%
F	Poor Approach to the building	13	40.62%	C	2	12.5%
				N	11	68.75%
G	Functional problems	10	31.25%	C	0	0%
				N	10	62.5%
H	Aesthetic ignorance	20	62.5%	C	6	37.5%
				N	14	87.5%
I	Poor composition of form	17	53.12%	C	4	25%
				N	13	81.25%
J	Unsuitable standards	13	40.62%	C	1	6.25%

				N	12	75%
K	Unsuitable spatial relations	16	50%	C	2	12.5%
				N	14	87.5%
L	Unsuitable separation of Private and public zones	13	40.62%	C	0	0%
				N	13	81.25%
M	Poor interior design	20	62.5%	C	5	31.25%
				N	15	93.75%
N	Poor providing of views	19	59.37%	C	4	25%
				N	**15**	**93.75%**

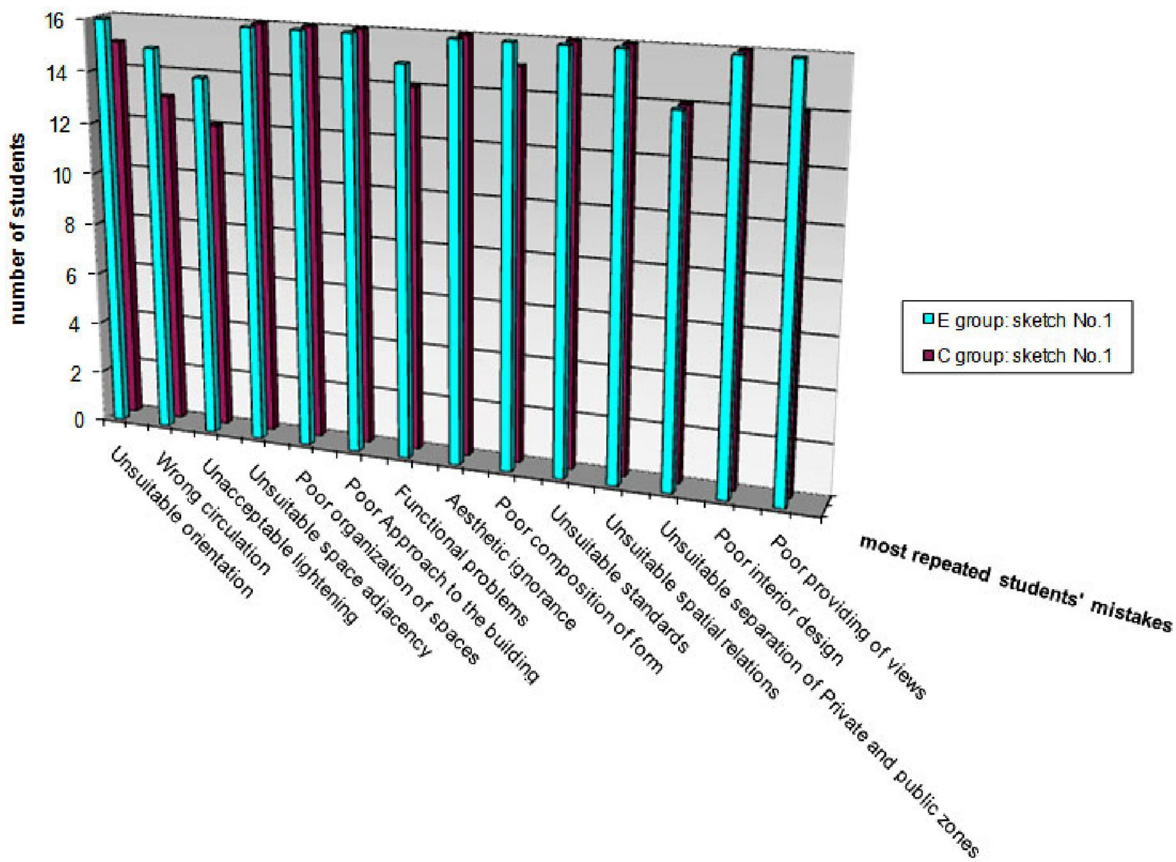

Figure 1. Comparison between experimental and control group in sketch number one

4. Discussions

The findings indicate that the application of constructivist educational theory in architectural design instruction can lead to acquisition of tacit knowledge. The rate of students' design mistakes in the experimental group decreased meaningfully between two similar designing exams taken at the beginning and at the end of a nine-month period.

The students' knowledge that was required through constructivist educational instruction was retained for a longer time than the knowledge that was obtained through other educational strategies.

The experimental group's mistakes decreased from 93.75 percent in sketch number one, to 17.85 percent in sketch number two. Such a high reduction in similar mistakes indicates that these students retained knowledge for a longer period of time. The length of time that a learner can retain learnt knowledge is one of the exterior indicators of tacit knowledge acquisition that can be inspected.

Meanwhile the control group's mistakes decreased only from 93.37 percent in sketch number one, to 79.4 percent in sketch number two. Such a low reduction in repeating mistakes among the control group indicates that the students did not retain knowledge for long, meaning that the acquisition of tacit knowledge through instructional methods other than constructivist methods did not occur meaningfully.

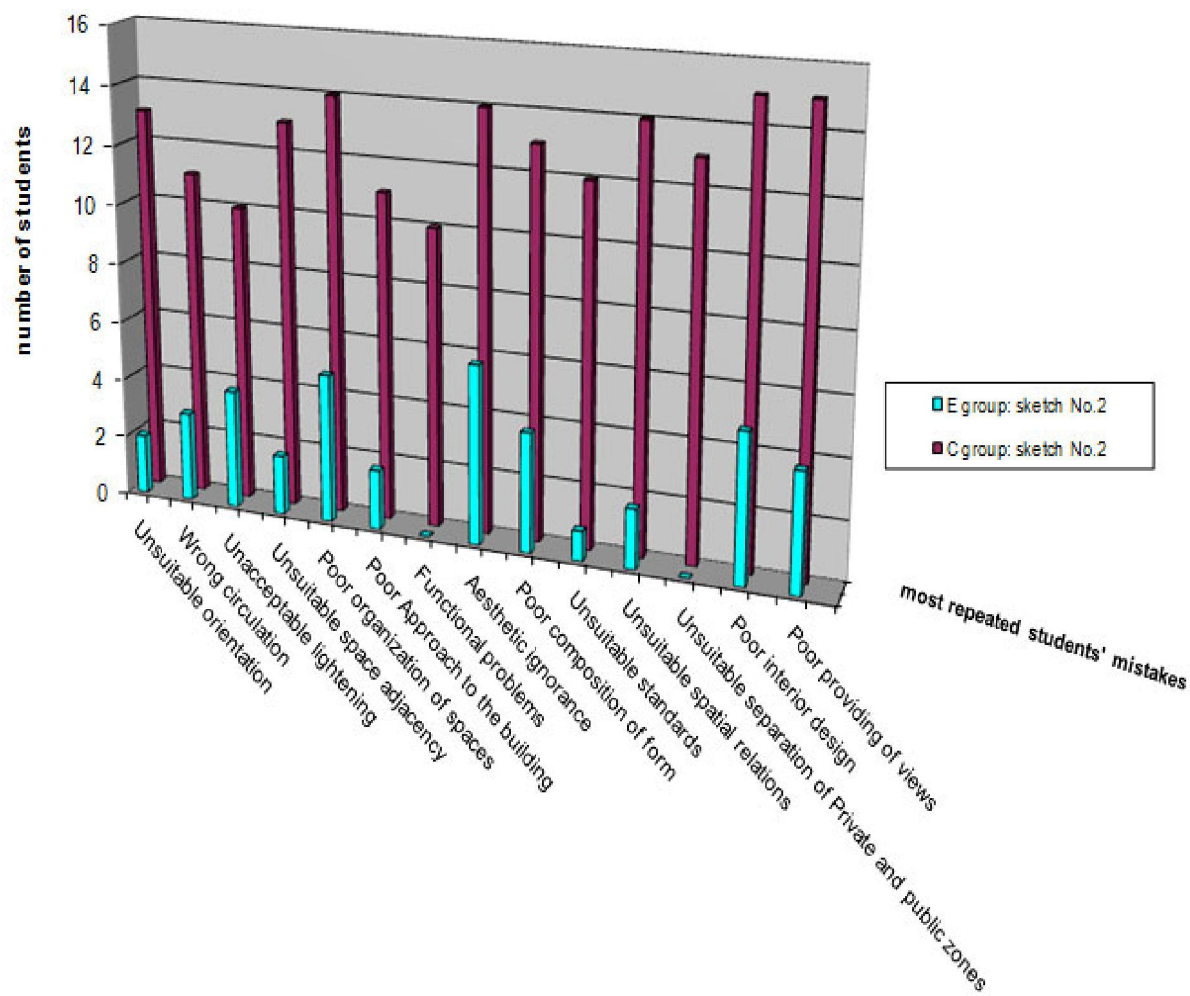

Figure 2. Comparison between experimental and control group in sketch number two

Figure 4 shows that the control group made little progress and the rate of mistakes decreased by only about 14 percent. This reduction is due to the result of instructional strategies other than constructivist theory. This effect is negligible when compared to the effect of constructivist strategy, for which mistakes declined about 76 percent. The findings indicate that the effect of constructivist instruction in design education is 5.4 times stronger than more traditional strategies.

In the present study, a significant relationship was found between application of constructivism educational theory and students' tacit knowledge acquisition, which ensured the ability to retain knowledge over a long period of time. The capability of architecture students to retain academic knowledge in their future professional careers as architects is an educational desire, confirmed by many researchers. Salama, in a number of studies on architecture education (1995, 1998 & 2005), argues about the inefficiency of the mechanistic orientation of pedagogy typically used in architecture schools today.

The student is evaluated with respect to his/her ability to reproduce what he/she has been told or shown. In turn, examinations are tests of the ability to reproduce material previously presented (Salama 2005, 3).

Students do not retain or internalize the knowledge made by mechanical orientation in their future professional careers. Because this orientation in pedagogy does not serve students with opportunities to construct and explore the required knowledge of design for their own work, instead of receiving it as readymade 'body of knowledge.' (Salama 2005, 9). The systemic pedagogical orientation, recommended by Salama (2005) for shaping students' future professional careers, resembles the results achieved from the constructivist instruction with the experimental group.

Based on an analysis of a number of studies (Anthony 1991; Boyer and Mitgang 1996; Cuff 1991; Koch et al 2002; Sanoff 2003; Schon 1981, 1983, 1985, & 1988; Stamp 1994; Teymur 1996), contemporary methods of design education suggest that gaps exist between knowing 'that' and knowing 'why and how' during the act of designing. While the students are only the receivers of knowledge, not constructors or explorers, they know the 'that' of the cases, but if they take part in knowledge construction and exploration, they may arrive the realm of knowing "why and how," which is more long-lasting. Carroll et al. (2010) cite a design instructor's point of view about the design studio's instruction philosophy, which is reminiscent of constructivist instruction.

So any kinds of projects that come in and talk about, 'We're not just going to think about a problem, but we're going to think about how to think about a problem,' is huge. (Carroll et al. 2010, 47).

On the same line, Peter Rowe (1987) refers to professional design education by introducing the concept of actionable knowledge, which is defined as knowing'that' and 'how' intertwined. Actionable knowledge cannot be simply a matter of theory and practice, but a different kind of knowledge upon which professional design education must be fundamentally focused (Schon 1983). Such pedagogy, which results in long retention of the acquired knowledge, is also in accordance with the results achieved from the present empirical study with an application of constructivist educational strategy in design education.

4.2. Limitations

This study featured a small design instructor to student ratio that does not reflect all design studios. This was due to the special character of constructivist instructional strategy which takes a much longer time than traditional direct studio instruction typically used. The definition of tacit knowledge in the present study was based on one of the exterior properties of this kind of knowledge, which is its permanence in time. This property had the capability of being examined after passing a considerable amount of time. This was due to the fact that it is not easy to monitor transfer of knowledge, which may be explicitly recognized only *post facto* at a later stage in one's development. Thus, students' ability to retain the learnt knowledge over a length of time was chosen as an indicator to show that the knowledge had been transformed to tacit knowledge.

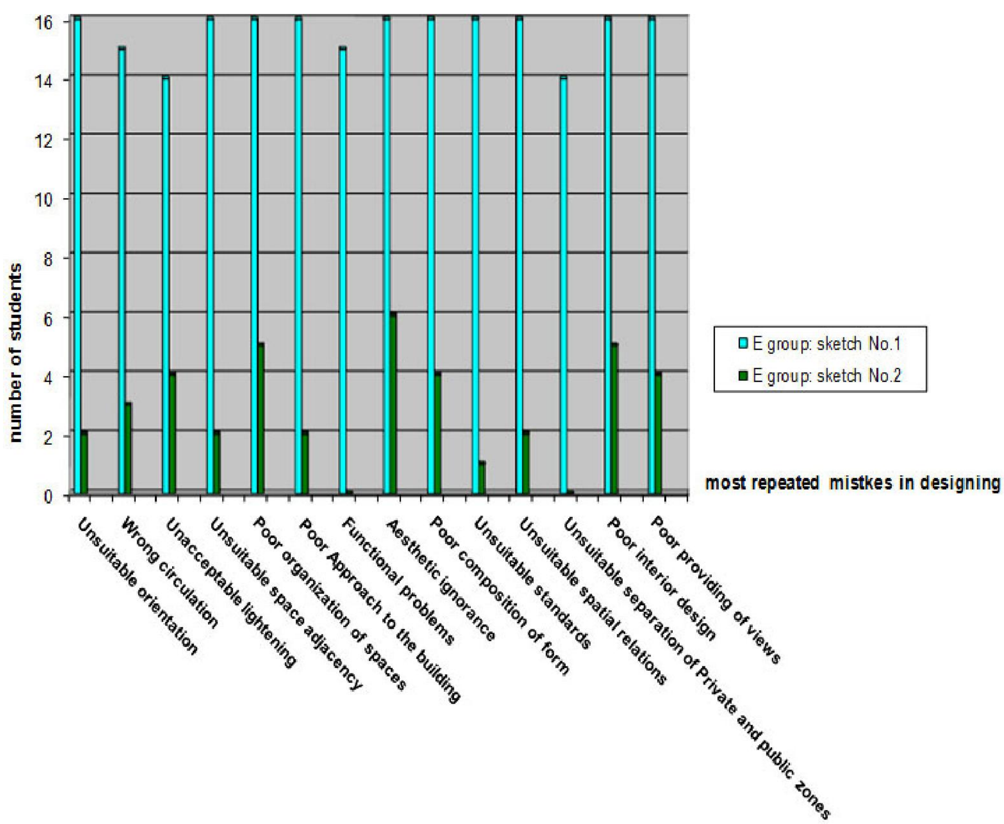

Figure 3: Comparison of students' mistake repeats between sketch number one and number two in experimental group.

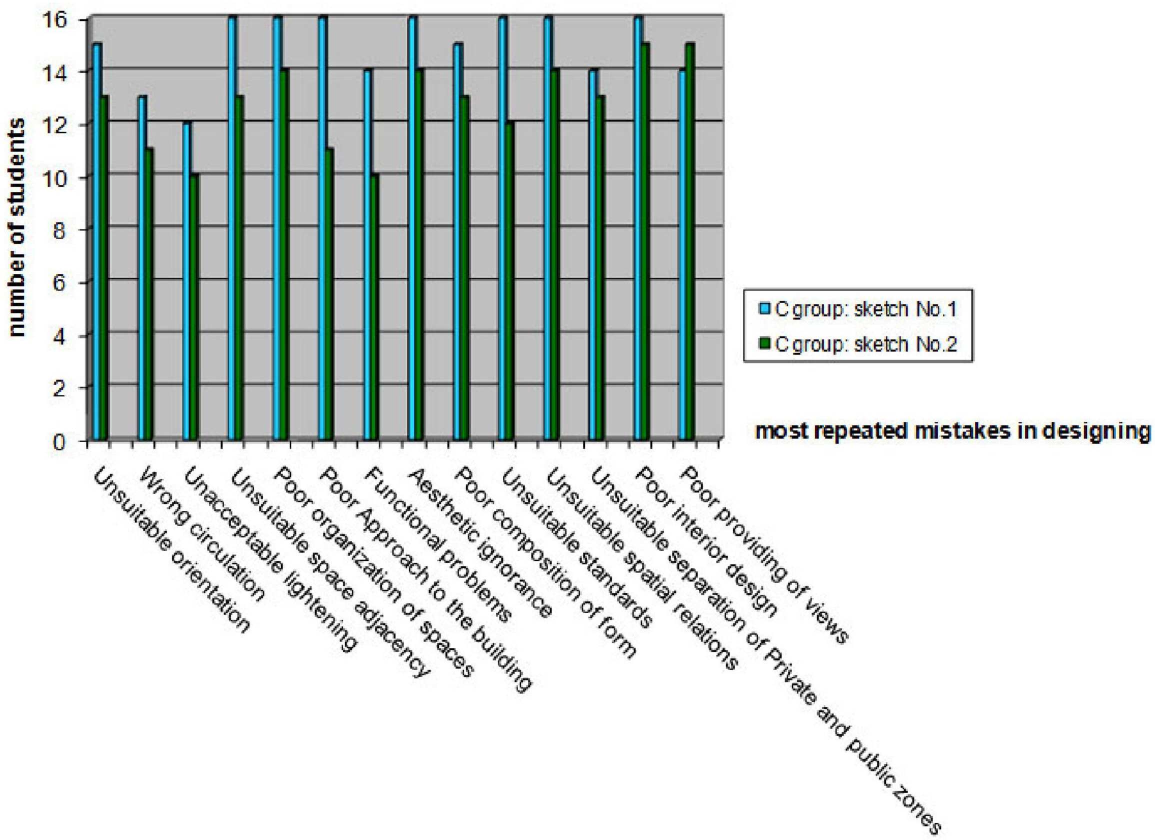

Figure 4. Comparison of students' mistake repeats between sketch number one and number two in control group

4.3. Conclusions

In this study, constructivist education became part of the design studio learning environment in diverse ways. The findings indicated that the application of constructivist educational theory in architectural design instruction can lead to tacit knowledge acquisition. A direct relationship was noticed between this educational theory and students' ability to retain knowledge over time. This capability, defined as tacit knowledge acquisition in this study, leads to the ability of future architects to make independent decisions. In the final analysis, the summary of constructivist methodology for design education in the light of the reviewed studies in this article, which could be accomplished in favor of a computer-aided design studio, is reviewed below.

Step 1:

1- Define real-world problems and support the essential research to redefine the design problem
2- Guide students to gather the required information relevant to the design problem
3- Establish critical arguments regarding the design problem
4- Familiarize students with the different aspects of the design context and environment

Step 2:

1- Allow learners to develop, compare, and understand multiple perspectives on an issue
2- Emphasize knowledge construction and not reproduction during the design process
3- Emphasize problem-solving, exploration, critical thinking skills and deep understanding in knowledge construction
4- Display 3D modeling of the proposed design

Step 3:

1- Direct students to self-criticize and self-mentor their design
2- Synchronize the design phase with the evaluation phase of the design process, as assessment is authentic and interwoven with teaching in the constructivist view.

The application of constructivist educational methodology in design education transfers the responsibility for design decisions from the instructors to the students, thus improving the critical thinking skills of the students and enabling them to gain confidence in their decision-making capacity. Constructivist instruction may help students become empowered agents in their own learning who possess both the tools and the confidence to change the world.

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