

**EVALUATION OF THE FACTORS THAT INFLUENCE
ARCHITECTURE DESIGN STUDENTS USAGE BEHAVIOR
AND BEHAVIORAL INTENTIONS TOWARDS USING
COMPUTATIONAL DESIGN TOOLS**

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Arwa Elmashharawi

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ARCHITECTURE DESIGN STUDENTS USAGE BEHAVIOR
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COMPUTATIONAL DESIGN TOOLS**

Approved by:

Associate Professor Murat Şahin,
Department of Architecture
Özyeğin University

Associate Professor Aslı Ağırbaş,
Department of Architecture
Özyeğin University

Associate Professor Nilay Ünsal Gülmez
Department of Architecture
Bahçeşehir University

Date Approved: 4 January 2023

ABSTRACT

Since the advent of computational design technologies, architectural design education in Turkey has undergone qualitative advancements. These changes have not only influenced the design curricula but have also created challenges for students to adapt to these advancements. Existing research on Computational design tools (CD tools) focuses on assessing design students' views, perceptions, and attitudes toward utilizing these tools. This research aims to evaluate final-year architecture design students' usage behavior and behavioral intentions toward using various types of computational design tools by exploring the behavioral, technological, and environmental factors that affect their behavior. The proposed research model is based on The Unified Theory of Acceptance and Use (UTAUT). UTAUT is a highly influential and robust model for comprehending the usage of technology systems.

The research employs a quantitative approach to collect and assess the data statistically. Descriptive and Linear Regression Analyses are executed to conduct the analysis. The results reveal that Effort Expectancy (EE) and Attitude (AT) do not influence Usage Behavior (UB), while Social Influence (SI), Facilitating Conditions (FC), and Self-efficacy (SE) have a moderate influence on Usage Behavior (UB). Performance expectancy (PE) and Anxiety (A) have a weak influence on Usage Behavior (UB). It is concluded that Usage Behavior moderately influences students' Behavioral Intentions (BI) to use the CD tools post-graduation. The current research

intended to contribute to the literature on architectural education curricula, especially when adopting new CD tools.



ÖZETÇE

Hesaplamalı tasarım teknolojilerinin ortaya çıkışından bu yana, Türkiye'de mimari tasarım eğitimi niteliksel ilerlemeler kaydetmiştir. Bu değişiklikler ,yalnızca mimarlık ve tasarım müfredatını etkilemekle kalmadı, aynı zamanda öğrencilerin bu gelişmelere uyum sağlamaları için çeşitli zorluklara da neden olmuştur. Hesaplamalı tasarım araçlarına (BT araçları) ilişkin mevcut araştırmaların, genellikle tasarım öğrencilerinin bu araçları kullanmaya yönelik görüşlerini, algılarını ve tutumlarını değerlendirmeye odaklandığı görülmektedir.

Bu araştırma, son sınıf Mimarlık öğrencilerinin, davranışlarını etkileyen davranışsal, teknolojik ve çevresel faktörleri tespit ederek, farklı türdeki hesaplamalı tasarım araçlarını kullanmaya yönelik kullanım davranışlarını ve davranışsal niyetlerini değerlendirmeyi amaçlamaktadır.

Önerilen araştırma modeli, Birleşik Kabul ve Kullanım Teorisine (BKKT) dayalı olarak formüle edilmiştir. Sözkonusu modelin, teknoloji sistemlerinin kullanımını anlamak için oldukça etkili bir araç olduğu gözlenmiştir. Bu çalışmada verileri istatistiksel olarak toplamak ve değerlendirmek için nicel bir yaklaşım kullanılmıştır. Burada analizin gerçekleştirilmesi için Tanımlayıcı ve Doğrusal Regresyon Analizleri yapılmıştır. Sonuçlar, çaba beklentisi ve tutumun kullanım davranışını etkilemediğini, sosyal etkinin, kolaylaştırıcı koşulların ve özyeterliliğin kullanım davranışı üzerinde orta düzeyde bir etkiye sahip olduğunu ortaya koymaktadır. Performans beklentisi ve kaygının, kullanım davranışı üzerinde zayıf bir etkiye sahip olduğu görülmüştür.

Kullanım davranışının, öğrencilerin mezuniyet sonrası BT araçlarını kullanmaya yönelik davranışsal niyetleri üzerinde orta düzeyde bir etkiye sahip olduğu sonucuna varılmıştır. Mevcut araştırma, ayrıca yeni BT araçlarının benimsenmesinde mimarlık eğitimi müfredatına ilişkin literatüre katkıda bulunmayı amaçlamıştır.



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CHAPTER I

INTRODUCTION

Architecture has always embraced innovative ideas, neoteric materials, and advanced technologies. The emerging avant-garde computational design technologies in architecture notably differ from the conventional prior ones in that they embrace distinct and divergent approaches and techniques. Designers tended to utilize computer-aided systems as drafting tools mimicking the analog paper-based design process. At the same time, computation-based design grasps the advantages of computer-aided systems (CAD) and allows designers to exploit the latent power of CAD systems [1]-[3]. These state-of-the-art computational technologies have taken a vital place in both the education and practice of architecture.

Among the early attempts to introduce a computational design approach to architectural education were by William J. Mitchell, Robin Ligget, and Thomas Kvan in their book *The Art of Computer Graphics Programming* in 1987 [4], [5]. Subsequently, several works have further explored the role of computational technologies in architectural education, which include works by William Mitchell [6], Terry Knight [7], Gabriela Celani [8], and Mark Burry [9], [10].

Since the proliferation of computational design technologies, architectural design education in Türkiye has experienced qualitative developments in which not only the design curricula were affected, but challenges were created for educators and students to cope with these developments. Therefore, significant efforts have been made to integrate these emerging technologies within the architectural design curricula [5],

[11]-[19] as designing with CAAD is no longer mimicking conventional design tasks of analog systems of the paper-based designing process [20]. Moreover, the evolution of contemporary computational approaches, techniques, and tools has changed how designers think, behave, and display their designs [20]-[22].

In this context, various endeavors have been made to examine architecture design students' behavior in terms of students' views, perceptions, and attitudes towards utilizing computer-aided and computational design technologies, as will be detailed in Chapter 2 [8], [23]-[33].

From a theoretical point of view, several theories and models have been developed to assess what affects designers' behavior from different perspectives; for instance, adopted from psychology, the Theory of Reasoned Action (TRA) focuses on the individual attitude and the subjective norm toward certain behavior [34], while Technology Acceptance Model (TAM) which is adopted from information systems domain focuses on the technology contexts -computer-based information systems - such as Perceived Usefulness and Perceived Ease of Use of a system and its effects on the user's acceptance of the system [35]. Another theory adopted from sociology, Innovation Diffusion Theory (IDT), has been used to study the technology innovations and the process of adopting the technology by users through studying the innovation attributes such as "Relative Advantage", "Compatibility", and "Complexity" that affects the rate of the adoption of the technology by its users [36].

Inspired by the previous theories and several other theories, Venkatesh, Morris, Davis, and Davis in 2003 have reviewed, compared, and combined these theories and revealed a unified model called the Unified Theory of Acceptance and Use of

Technology (UTAUT) that assess the behavior of the user toward technology from a holistic point of view [37]. This model holds significance because it highlights the potential impacts of social, personal, and enabling factors on the usability of a system [38]. UTAUT has inspired many researchers to conduct studies on user behavior towards information technology applications and software in different domains such as architecture and construction, health, education, and governmental sector [37], [39]-[41].

However, there is a relative lack of research in the architectural design education, specifically evaluating the determinants influencing students' current usage behavior and behavioral intention to use the tools in the future. Based on this, a research gap has been identified. This study aims to study architecture design student's usage behavior and behavioral intentions to use computational design tools based on the Unified Theory of Acceptance and Use of Technology (UTAUT). Seven constructs adopted from the UTAUT model are examined: Performance expectancy, Effort expectancy, Attitude toward using technology, Social Influence, Facilitating conditions, Self-efficacy, and Anxiety, as will be detailed in Chapter 2.

1.1 Statement of the Problem

The rapid advancements and popularization of different computer programs adopted within the architectural education discipline have impacted the design process and students' behavior toward these technologies [26], [31], [42].

Research shows that with the increasing use of various computational design tools by architectural design students in their design projects, different behavioral

patterns have emerged, affecting students' motivation, performance, creativity, acceptance, and tendency to use these tools and their future decisions regarding their architectural careers [23], [30], [31], [37], [43]-[45]. Accordingly, efficient technology adoption and utilization are built on the user's developed behavior toward this technology [37].

A distinct number of factors can influence students' usage behavior of technology. Thus, the problem of this study is that there is a need to evaluate architecture design students' usage behavior towards computational design tools by identifying and assessing the direct and indirect factors that affect their usage behavior. Such investigation might be helpful for educators within the architectural education discipline as acknowledging the factors that impact the current situation of students' usage behavior toward various types of these tools might help them in improving educational programs and providing suitable support for the students within the needed aspects based on the gained information about students' usage behavior [46].

Based on theories and models adopted from psychology, sociology, and information technology, various academic studies have been conducted to study the factors that affect design students' usage behavior towards emerging computer technology within architecture design curricula [38], [44], [47], [48]. Additionally, other studies focused on assessing architectural design students' perceptions and attitudes toward these new technologies [8], [23]-[26], [49]-[52].

In the light of the literature review conducted, it is found that there is a relative scarcity of research in the architectural education context regarding this area:

- Holistic evaluative studies on students' usage behavior and behavioral intentions towards computational design tools, such as studies that utilize the Unified Theory of Acceptance and Use of Technology (UTAUT).

Thus, the present is conducted based on the UTAUT model and examines the influence of its seven constructs on architecture design students' usage behavior and behavioral intentions [37].

1.2 Aim and Objectives and Research Questions

This thesis evaluates final-year architecture design students' usage behavior and behavioral intentions toward using various computational design tools. It focuses on final-year students in the concluding phase of their undergrad academic journey. The choice of final-year students is deliberate, considering that this study seeks to assess their usage behavior and its correlation with behavioral intentions post-graduation. The study was conducted at the Faculty of Architecture and Design at Ozyegin University in Türkiye. Based on the literature provided earlier, this study has been formulated around the primary research question derived from this thesis's ultimate goal: What are the critical behavioral, technological, and environmental factors that affect students' usage behavior, which in sequence affect their behavioral intentions to use the system in the future?

The answer to the primary research question can be obtained through an evaluation of the factors that affect students' usage behavior and behavioral intentions based on the unified theory of acceptance and use of technology (UTAUT). The main objectives of the thesis have been identified as follows:

- Identify the direct and indirect factors affecting students' usage behavior toward CD tools.
- Obtain data through self-assessment on the usage patterns, general experience, and preferences of CD Tools by final-year design students.
- To ascertain if usage behavior affects students' willingness and intentions to use CD tools post-graduation.

Based on the above objectives, the following research questions have been developed:

- What direct and indirect factors affect design students' usage behavior of CD tools?
- What are the usage patterns, conceived experience, and preferences of CD tools by design students?
- Is there a relationship between usage behavior and behavioral intentions to use the CD tool post-graduate?

1.3 Relevance of the Study

Since users' behavior towards a technology system in terms of usage behavior and behavioral intentions varies widely depending on distinct factors [37], it is necessary to identify and evaluate these factors to understand the current situation of design students'

usage behavior toward various types of these tools and assist their behavioral intentions to use them in the future.

When reviewing the existing literature about students' behavior toward computational design technology, it is found that there is a significant amount of studies that evaluate students' perceptions and attitudes towards utilizing computational design technology in architecture design education as mentioned earlier.

This study intends to contribute by providing a contextual perspective in evaluating final-year architecture design students' usage behavior and behavioral intentions toward computational design technology through a holistic model, the Unified Theory of Acceptance and Use of Technology (UTAUT). Moreover, this research can provide important insights into the direct and indirect factors that mostly affect students' usage behavior, and based on that, educators can get valuable insights for their decisions regarding the development of a design curriculum according to students' needs. Such assessment is important within the architectural education discipline as it also helps educators in improving computer-aided design labs and providing suitable support for the students within the needed aspects based on the information of students' usage behavior [46].

Laurillard [53] emphasizes the importance of conducting evaluations at all stages during the design, production, and integration of educational courseware. Whether the courseware constitutes an entire course, a portion of a course, or a specific session or teaching resource, they are all regarded with equal significance in the evaluation process [53].

Thus, the potential of the research in this area is expected to add a theoretical contribution to architecture design education research on computational design technology acceptance and use.

1.4 Limitations of the Study

One of the limitations of this research is related to the UTAUT model which is utilized in this study. Based on the “framework and criteria of theory evaluation” by Weber [54], he articulated several criteria to evaluate theories within the discipline of information systems in which the strengths and weaknesses of a theory can be determined. Among these criteria are “parsimony” and “level” of the theory.

According to Weber’s [54] framework, the UTAUT model has two limitations: first, it is relatively low parsimony as the UTAUT model includes many constructs to capture a comprehensive explanation of what it studies [54], [55]. However, parsimony dictates that the goal is to achieve a high level of explanation with a few constructs/ theoretical components [54]. The second limitation is that the UTAUT model was formulated to be used at the micro-level as it focuses on the individual/ users of a technology [55]. However, as Weber [54] articulates, the appropriate level of a theory is the middle range or “Meso-level.”

1.5 Research Methods

This research has been conducted in two stages (Figure 1). In the first stage, a secondary research method (literature review) was adopted to collect existing related literature that shaped the background information and the foundation for designing the primary

research [8]. In the second stage, a quantitative approach was utilized [56] with a close-ended questionnaire survey from UTAUT to evaluate design students' adoption of computational design tools.

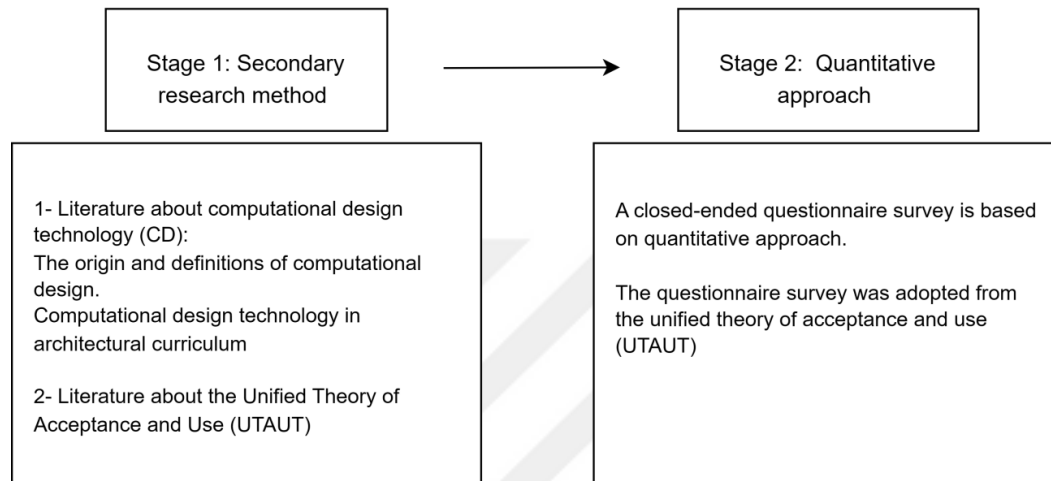


Figure 1: Research stages

1.6 Thesis Content

This thesis covers six chapters as follows:

Chapter 1: Introduction; this chapter consists of a brief introduction about the research background, research problem statement, research scope, research aim and objectives, relevance and limitations of the study, and research methods.

Chapter 2: Literature Review; this is divided into two main sections, the first presents literature about computational design technology and related theoretical contents, while the second section provides literature about utilizing the unified theory of acceptance and use of technology theory (UTAUT) in evaluating design students' behavior towards CD tools.

Chapter 3: Research model and hypotheses; this chapter presents the research model and the hypotheses.

Chapter 4: research methods; this chapter articulates the research methodology and detailed explanation of the data collection methods.

Chapter 5: findings and data analysis; this chapter displays the findings of the research and presents the data analysis.

Chapter 6: Conclusions and recommendations; this chapter consists of a discussion of the results of the findings and suggestions are made for future studies.

CHAPTER II

LITERATURE REVIEW

This chapter presents a review of the existing literature from two distinct academic disciplines: (1) the computational design technology from the information system discipline and (2) the behavioral theories from psychology and sociology disciplines as the main objective of this thesis is concerned about evaluating the usage behavior and behavioral intentions of architectural design students towards computational design tools. Within the scope of this research, several topics were reviewed:

1. Computer-aided design and computational design technology overview.
2. computational design technology definitions
3. Computational design tools classifications.
4. The integration of computational design technology in architectural curriculum.
5. Introduction to the Unified Theory of Acceptance and Use of Technology (UTAUT).
6. The determinants and moderators of the unified theory of acceptance and use of technology (UTAUT).
7. Behavioral intentions and usage behavior in the UTAUT model.

2.1 *Computational Design Technology*

2.1.1 Computer-Aided Design-Systems

Since the birth of computer-aided design system (CAD) at an experimental level at the end of the '50s by Dr. Patrick J. Hanratty, CAD systems have passed through a rapid progression that shaped its capabilities as a tool to aid architects and designers [57].

In 1970 when Nicholas Negroponte, a leading exponent of the infusion of computer processes into architecture, published his book “The Architecture Machine”, he shed light on the future of CAD with anticipation that the computer would act as a design partner and as an intelligent machine that can learn, understand, self-improve and associate the designer with its artificial intelligence [58], [59]. However, the complexity of such operations and the limited capabilities of the computers at that time made the mission hard.

A few years later, William John Mitchell differentiated in his book *The Theoretical Foundation of Computer-Aided Architectural Design* in 1975, two levels of CAD as an aid to the designer, the first level as drafting, representation, and communication tool that makes precise blueprints, while the other level is to give the machine the role to explore design ideas and to act as a design problem-solver based on the designer previous considerations [2], [8], which what is called in another word “computational design”. Although the Computational Design term (CD) arose in the research and was found as a keyword in the literature only in the late 1990s, the term can be traced back to only one CD-related article published before 1960 in CuminCAD [60] and was adopted as an approach in architectural design theory in *The Design Methods Conference* in 1962 [61]. Afterward, attempts were carried out to integrate

computational design in architecture through publishing position papers by Eastman in 1975, March and Steadman in 1971, and Mitchell in 1977. In addition, during the same period, several Ph.D. theses on CD in architecture were published by Akin in 1979 and Yessios in 1973 [60].

Moreover, Mitchell [57] pointed out a critical moment in the history of Computer-Aided Design (CAD) during the 1980s when it gained widespread popularity. He noted that following this period, the broader potential of CAD technology was largely overlooked. This led to CAD packages becoming standardized and resembling basic word-processing software used primarily for drafting. Consequently, highly capable machines are utilized way below their full potential, engaging in repetitive tasks that have the advantage of using time more efficiently. However, most importantly, designers miss out on the opportunities to discover new designs through complex computational possibilities that are difficult to imagine when working manually [57].

Since then, incessant research and developments in computer-aided design systems resulted in a boom in the computer's capabilities to perform complex computations that enabled the designers to exploit the latent computational power in CAD systems [62]. The application of computational design in architecture practice and education results from the advances in CAD systems and tools [63].

Today, computational design is not only constrained to dealing with intelligent machines and exploiting the computation powers of the computer to generate complex designs, but computational design has become an interdisciplinary approach that is formed by a symbiosis of knowledge, theory, methods, and tools. Computational design

presents an accumulation of multilayered concepts adopted from computer science, mathematics, system science, philosophy, and artificial intelligence [21], [64], [65].

Furthermore, the innovations in the technology of computational design not only influence the end product and the outcome of the architectural design as building forms, space, and structure but also affect the design processes and procedures, fabrication, and construction methods of the building [63], [66].

Lately, the increased capacity of computational tools and techniques such as simulation, analysis, performance-based design, evolutionary, optimization, virtual construction and digital fabrication methods, and building information modeling (BIM) [a63], [67] as well as the diversity of computational design approaches which include, but are not limited to generative design, algorithmic design and parametric design used to aid the design process. These methods empower the designers to explore complex solutions, enhance the design process, and control the design process at different stages [60].

It is important to note that computational design is not necessarily a design made with the help of a computer [8]. It is a mode of logical thinking and a procedural reasoning process to solve ill-defined design problems [68], [69], [70] whether the computer was used or not. The concept of computational design thinking (CDT) was discussed in detail by Kostas Terzidis in his book *Algorithmic Architecture* and Menges and Ahlquist in the book *Computational Design Thinking* [65], [71]. Terzidis described computation as not vitally attached to the digital and it is a procedure of logical thinking and exploration of indeterminate, vague, unclear, and ill-defined processes that take place to solve design problems [75], [73]. It is the mental process of analyzing

information, codifying, systemizing, and synthesizing it without the use of computers [72]. The root of CDT was adopted from Cybernetics theory [74] and system theory [75] which entails mapping procedural steps and feedback loops in solving a design problem. This frees computation from the engagement with particular software [72]. Computational design existed before the invention of computers for instance when analog computation was the base of Frei Otto's physical model-making with minimal surface experiments of visual properties of the material [60], [76].

Computational design in architecture has a rich history that predates the invention of digital computers. For instance, in the realm of architecture, analog computation played a pivotal role. Renowned architect Frei Otto leveraged analog computation in his physical model-making processes, particularly in experiments with minimal surface designs. These experiments, conducted without the aid of digital technology, explored the visual properties of materials and exemplified early computational thinking [60], [76]. Similarly, artist Sol Lewitt's artworks were guided by sets of instructions, showcasing how computational design principles, such as rule-based systems, could be employed to create diverse art pieces through the interpretation of instructions and constraints [69]. Furthermore, the work of Gaston Julia in the 1920s and Benoit Mandelbrot in the 1970s, though initially expressed on paper, depended on computational graphics for visualization, understanding, and further exploration [68]. Furthermore, in 1991, Mark Burry initiated a significant exploration of computational design by delving into the geometric aspects of Antoni Gaudí's columns in the Sagrada Família church. Gaudí's architectural concept envisioned the church as a forest with a canopy-like nave ceiling supported by slender stone [10]. This exploration demonstrated

the application of computational design before the digital era, highlighting its potential for pushing architectural boundaries.

With the departure from the first level of CAD as a drafting tool to a computational tool and all the possibilities that computational design technology added to the architectural design field, architectural practice and education attempted to transpose the old methods of designing and expand the usage of the strong capabilities and computation power of computer systems [24], [55], [77].

2.1.2 Computational Design

By the middle of the 20th century and with the gradual advent of the information technology age, architectural design -as other disciplines- witnessed a radical shift in the design paradigm, where the increased diffusion of the use of computers and computer software in design caused an unprecedented metamorphosis in architectural practice and education. Design with computation has introduced innovative approaches of conception, design, and production, firmly establishing computers and computing as essential elements in today's architectural design field.

The computational design approach has evolved through the fusion and integration of interdisciplinary domains. It is based upon multilayered knowledge from various fields including philosophy, computer science, mathematics, biology, system theory, cybernetics, artificial intelligence, and others. This symbiosis and synthesis of multidisciplinary insights has led to the rise of the computational design approach [21], [65], [64]. The concept of computational design involves the utilization of the computer's computational capabilities to create complex, multilayered, correlated

architecture projects through an approach characterized by exploration, rationalism, and logical and systematic thought processes [63], [72].

To fully grasp the concept of computational design, it is crucial to dissect the term "computation" and provide a definition of it. The etymology of the word "computation" is traced back to the Latin word "computare," where "com" conveys the meanings of "with" or "together," and "putare" signifies "clear up," "reckon," and "settle." Thus, "computare" essentially denoted the act of clarifying, settling, and reckoning things together [17]. The term "computation" was first used as a term in the 15th century, before the advent of computers and computer science development [17]. Accordingly, it is not a recent word, yet it was employed in ancient Rome to describe various arithmetic and non-arithmetic calculations. Grammatically, the term computation incorporates the suffix '-tion,' which signifies the state, condition, or quality of a process [72]. In other words, it represents the action and process of problem-solving that involves numbers or quantities.

In the realm of architectural design, various distinctness of computational design have been disclosed. As Celani [8] elucidates, computation in design is the action of performing logical operations whether carried out by computers or not. These operations are integral to design processes, including design generations (synthesis of the design), design representation (modeling of the design), and design evaluation (analysis of the design).

In his introduction to the book "The Electronic Design Studio", William Mitchell explains that computational design procedure depends upon malleable operations of shape algebra to derive precise solutions and draw conclusions from a complex initial

dataset. He emphasizes that computational design is about the treatment of design rules (Figure 2) that could be expressed as procedures that involve evolving, responding, shifting, and contradicting to derive inferences [6]. According to him, the spectrum of design computation spans from low to high complexities, as in the past designers were limited to low computational complexity, while in the present-day advanced computational capabilities enable designers to carry out much greater complexities in design processes [78].

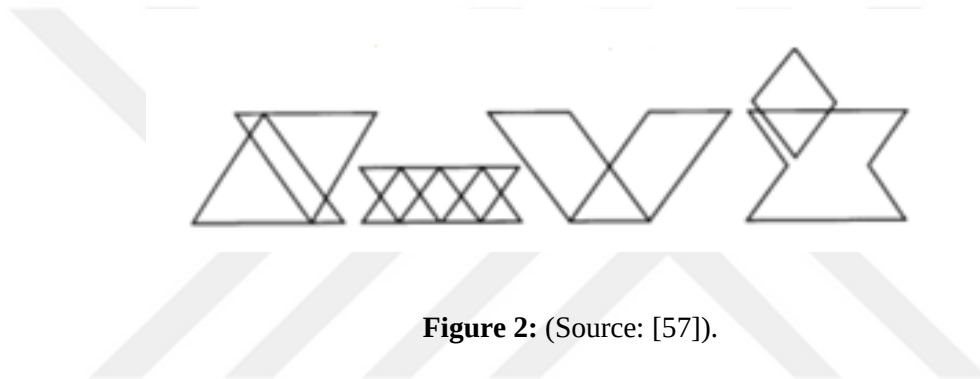


Figure 2: (Source: [57]).

Rocker [79] further tied the concept of computation within the field of architecture to the process of coding through using rules and principles. She argued that architecture, across its historical progression, has been rooted in coding as shapes and forms are conceived and evolved based on established rules, constraints, and principles. She elaborated that computation existed way before computers and was already a part of architectural practice long ago, where rules and systems governing design were expressed through traditional means like pencil drawings and physical models. The arrival of computers expanded the concept of coding from traditional, paper-based mediums to digital mediums. She denoted this shift as a "computational turn" [79].

In his writings in the book "Algorithmic Architecture", Kostas Terzidis delineates computational design as an exploratory endeavor, allowing designers to efficiently experiment wide range of design solutions and alternatives. This approach enables them to investigate various ideas, options, and possibilities. Terzidis goes on to elaborate on the characteristics of computational design, emphasizing its rational, logical, and systematic qualities, which involve the application of logical reasoning, rational thinking, and methodical approaches within the design process [73]. Importantly, computation stands as independent in nature, free from exclusive ties to a particular medium such as computers or, to some extent, the human brain; instead, it is a logical procedure that can be employed across different environments and devices including computers [80].

Implementing computational design within a computer system allows for the investigation of intricacies that surpass the limits of human prediction. It's important to note that this doesn't mean that computational design on a computer system is taking over the designer's role; rather, it extends the creative capacity of the human mind and imagination. To illustrate, the groundbreaking work of Gaston Julia in the 1920s and later Benoit Mandelbrot in the 1970s, though initially presented on paper, would not have been visualized, comprehended, and thoroughly explored without the computational capabilities offered by computers [72].

He also emphasized that the prevailing mode of utilizing computers by architectural designers today is that of computerization. He clarified that the term computerization is frequently misinterpreted as computation. Computerization primarily involves mimicking the act of designing through entering, processing and storing the information in the computer system. It often manifests as superficial, mouse-based

manipulations of three-dimensional computer models. In other words, computerization encompasses digitization, automation, and mechanization. In contrast, computation facilitates the exploration of design solutions within a computer system. It is using the computer as a design tool [72].

Terzidis suggested that one way of integrating computation into the design process is moving beyond mere mouse manipulation by delving into the designation and customization of software programs. This approach is known as Algorithmic design. Rather than engaging in direct programming, it entails translating design intentions into code using scripting languages found in three-dimensional software applications like Maya Embedded Language (MEL) and MaxScript, as they can establish uniformity, organization, coherence, traceability, and intelligence within computer-generated three-dimensional shapes [72].

Several other authors characterize computational design in architecture as an innovative approach that harnesses the latent potential of computers and digital tools during the design process. For instance, Negroponte introduced the concept of "The Architecture Machine", which suggests that the true role of computers in the design process is that of a "design partner" [58], [59]. His proposal regarding the intelligent machine acting as an assistant to architects in the design process is aligned with the computational approach in design [58]. This proposal emphasized an architect-machine collaborative partnership, establishing a dynamic and productive dialogue between them. According to Negroponte, this relationship is not one of servant and master but rather a synergy where both entities work together to exhibit solutions and alternatives for automating the design processes [59].

In his essay “Digital Morphogenesis” published in 2003, Branko Kolarevic offers a robust overview of the diverse digital design approaches that depart from the "conventional and centuries-old traditions" of architectural design to the contemporary computational design [81]. He has categorized these approaches based on computational process concepts, such as motion kinematics and dynamics (animate architectures), topological space (topological architectures), parametric design (parametric architectures), isomorphic surfaces (isomorphic architectures), genetic algorithms (evolutionary architectures), and keyshape animation (metamorphic architectures) [82].

Hence, as opposed to the traditional practice of designing the external form, contemporary computational approaches, techniques, and tools enable designers to articulate the internal logic of the design through non-linear, dynamic systems. These systems can alter to exhibit new, indeterminately, and unexpected outcomes. Moreover, in computational design models, the inclusion or removal of particular pieces of information can exert a significant influence on the behavior and configuration of the final result [81].

Ascending in popularity of the computational design paradigm was embraced by pioneering architects and theorists and can be seen in various works. Notable figures and their works such as Rivka Oxman (2017) in *Thinking Difference*, Nikos Salingaros (2012) in *Urbanism as Computation*, Mark Burry (2011) in *Scripting Cultures*, Kostas Terzidis (2006) in *Algorithmic Architecture*, Yehuda Kalay (2004) in *Architecture's New Media*, Branko Kolarevic (2000) in *Digital Architectures*, Greg Lynn (1999) in *Animate Form*, Herbert Simon (1998) in *The Sciences of the Artificial*, Frei Otto and Bodo Rasch (1995) in *Finding Form*, Peter Eisenman (1992) in *Visions Unfolding*, William Mitchell (1990) in *Logic of Architecture*, Yehuda Kalay (1989) in *Modeling*

Objects and Environments, Marcos Novak (1989) in Computational Compositions, George Stiny and Lionel March (1981) in Design Machines, Ömer Akin (1979) in Models of Architectural Knowledge, Nicholas Negroponte in The Architecture Machine (1970) and Soft Architecture Machines (1975), Christopher Alexander (1966) in Notes on the Synthesis of Form, to mention a few significantly contributed to illuminating and integrating computational design into the field of architectural design [8], [68], [72], [83].

2.1.3 Artificial Intelligence (AI)

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think and learn like humans. It encompasses a wide range of technologies and techniques that enable machines to perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation.

In the context of architectural design, AI can be employed in various ways to enhance efficiency, creativity, and problem-solving capabilities. There are several applications of AI in architectural design for instance AI algorithms can analyze vast amounts of data and generate design alternatives based on specified parameters. This helps architects explore a multitude of design possibilities and optimize for various criteria like aesthetics, energy efficiency, and structural integrity [84]. Moreover, AI algorithms can recognize patterns in large datasets, aiding architects in understanding user preferences, historical design trends, and contextual influences. This information can inform the design process and help create more user-centric and contextually

relevant architecture [85]. In addition, AI-powered VR and metaverse technologies provide immersive experiences, enabling architects to visualize and interact with their designs in a virtual space. This aids in better understanding spatial relationships and identifying potential design improvements [86]. The advent of the metaverse, a virtual space intertwining physical and digital realities, carries profound implications for the field of architectural design. Architects now have the ability to immerse themselves in virtual architectural spaces, fostering a more interactive and collaborative design process. This collaborative aspect extends beyond geographical constraints, allowing architects from diverse locations to engage in real-time collaboration within a shared virtual environment. Within the metaverse, architects can explore and visualize their designs in a highly realistic manner, offering a more comprehensive understanding of spatial configurations before physical construction begins. This capacity for simulation and visualization extends to testing and optimizing user experiences, considering factors such as accessibility, comfort, and functionality within virtual environments [86].

Sopher & Lescop [87] introduce the Immersive Atelier Model (IAM) based on VR and metaverse technology, a pedagogical approach in the context of architectural design education for remote inter-university studios using multi-user virtual environments (MUVES). The IAM aims to address the needs of remote studios. Findings highlight the supportive role of student-shaped MUVES in indirect learning and conceptualization acts. The IAM offers insights for expanding traditional ateliers and promoting sustainable quality education in remote settings, presenting an innovative use of MUVES as both educational and design spaces.

2.1.4 Computational Design Technology Classifications in Architectural Design

Computational technology in design has become popular among architects and designers. Researchers and theorists in the field of design have adopted different classifications to address different concepts, approaches, techniques, and tools within computational design technology. In this section, a synthesis and summary of these classifications will be presented to establish a general mind map and a comprehensive overview of computational design technology (Figure 3).

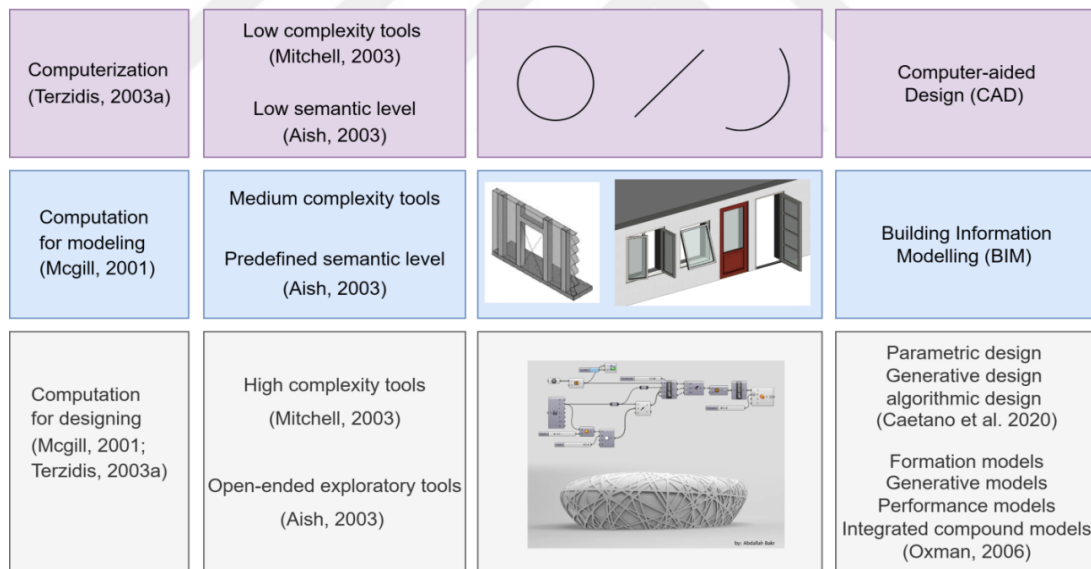


Figure 3: (Source: by author, images from: www.bimteknoloji.com www.outline.dk www.food4rhino.com)

The integration of computational technologies in architecture extended the capacity and increased the potential power of computers in design. Terzidis [72], [73]

highlights two modes of utilizing computers in architectural design today: computerization and computations. Computerization is a distinct term that is frequently misunderstood as computation. In his view “the dominant mode of utilizing computers in architecture today is computerization. Computerization, in its idiomatic sense, refers to inputting, processing, and storing data within a computer system. In other words, this process involves automation, mechanization, digitization, and conversion of predetermined and well-defined entities. The design entities the designer already conceives are inserted, processed, and stored in the computer. Furthermore, in his perspective, general mouse-based manipulations of the 3D model in design software are an act of computerization and are frequently mistaken for computation [72], [73].

In contrast, he elaborates that the other mode of utilizing computers is with computation. It is when designers take advantage of the computational power of the computer tools and exploit them as exploratory formal tools that often involve an ill-defined process. One of the choices to use computer tools as an exploratory and design tool is codifying the design using available scripting languages within the computer software (i.e. 3dMaxScript, Maya Embedded Language (MEL), and FormZ). Through the utilization of scripting language, designers can go beyond the constraints of the current 3D software and extend their designs beyond traditional mouse-based interactions [72], [73].

Mcgill [88] differentiates in her research between computation for designing versus computation for modeling. She explains that computational design is about generating designs ideas. Computation for modeling - or drafting - refers to the representation of the design. The main distinction is that in computation for modeling, the designer exploits computer-aided design (CAD) tools to exhibit his design in a

realistic scene after using hand sketching to generate and develop his designs. On the other hand, in computation for designing, the designer espouses digitally the formation process of the design in which the design process becomes explicit and can be altered at any stage to drive the desired outcome. In addition, the outcome is smartly connected to its process, and evaluation, optimization, and simulation techniques can be applied to it.

When speaking about computer software utilized in design, the phrase “computational design tools” serves as an encompassing umbrella that contains several design tools/software such as Computer-Aided Design (CAD), Building Information Modelling (BIM), analysis, optimization, and simulation tools [61], [63].

More technically, in his article, Aish [89] elaborates that designers are constrained with low semantic CAD tools (low semantic level: such as lines, circles, and arcs). These tools produced more efficient and precise drawings when compared to traditional pen and paper drawing tools. It serves as a suitable replacement for manual drafting. Later on, designers were limited to more advanced yet predefined tools (higher and predefined semantic level: such as walls, windows, and doors) that facilitated the automation of the design process and the integration of planning, designing, and representation phases with construction phases. According to him, the problem with these existing applications and tools is that they treat architecture and construction as a “closed domain” and as a “conservative force that reinforces conventions.” In contrast, a call for a nebulous and open-ended exploratory tool is needed that can create and manipulate geometric relationships [89].

Similarly, in his article, Mitchell [78] elaborates that designers have also been restricted with low computational complexity tools. However, with the advent of CAD

software, it has become feasible for designers to design with higher computational complexity tools.

In addition, now, with advanced technologies, designers have access to tools of greater computational complexity that empower them to transition from mere ‘form-giver’ to the controller of the generative process, where the ultimate design outcome emerges from the integration of the designer's creativity with the generative potential of computer tools [61].

The growth and the advancements of digital technologies in the field of architecture resulted in the emergence of various computational methods and tools that became popular among designers and architects. Caetano et al. [60] proposed a detailed taxonomy for the emerging approaches, techniques, and tools used under the umbrella of computational design technology. Their research reveals three main approaches in computational design technology: parametric design, generative design, and algorithmic design. These computational approaches incorporate and integrate different computational techniques used by designers, such as simulation, evolutionary optimization, and fabrication techniques. As for computational design tools, Caetano & Leitão [61] classified them as follows: Computer-Aided Design (CAD), Building Information Modeling (BIM), analysis, optimization, and simulation tools (Figure 4).

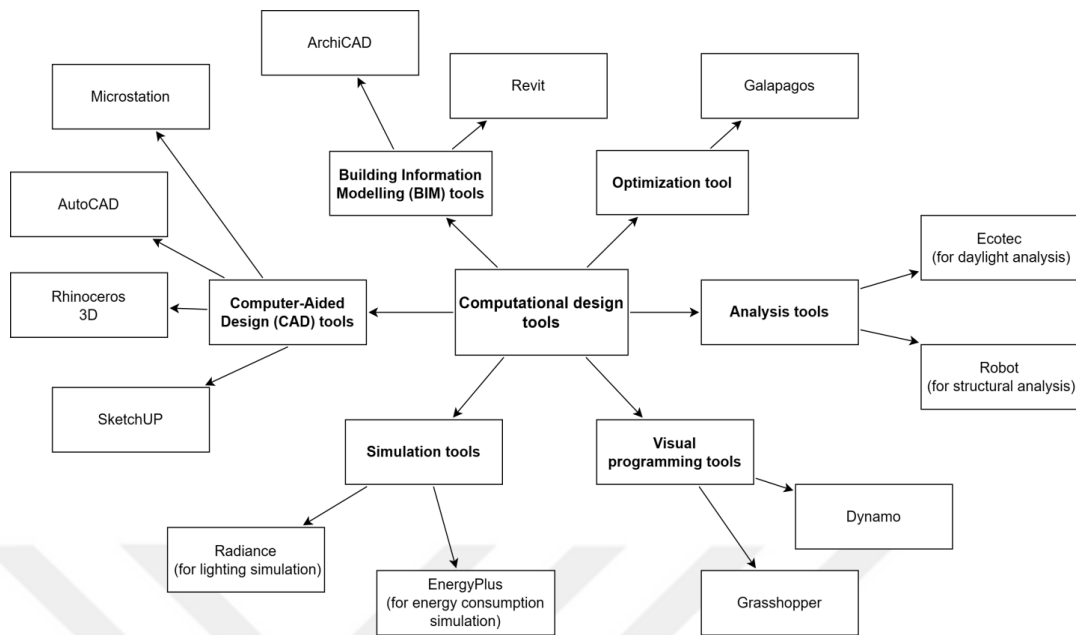


Figure 4: Computational design tools classification based on Caetano & Leitão [61]

In her pioneer work, Oxman [22] proposed a framework for the current digital design theories and methodologies of using computational design tools in the architectural design field. In brief, she classified five paradigmatic models of digital design, which incorporate: (1) CAD models, (2) Formation models, (3) Generative models, (4) Performance models, and (5) Integrated compound models (Figure 5). These models demonstrate the methodologies of utilizing computational design tools and explain the growing advancements in these tools. In addition, these digital models influence the entire design process from conception to construction and empower the designer to be a toolmaker to create customized computational design tools.

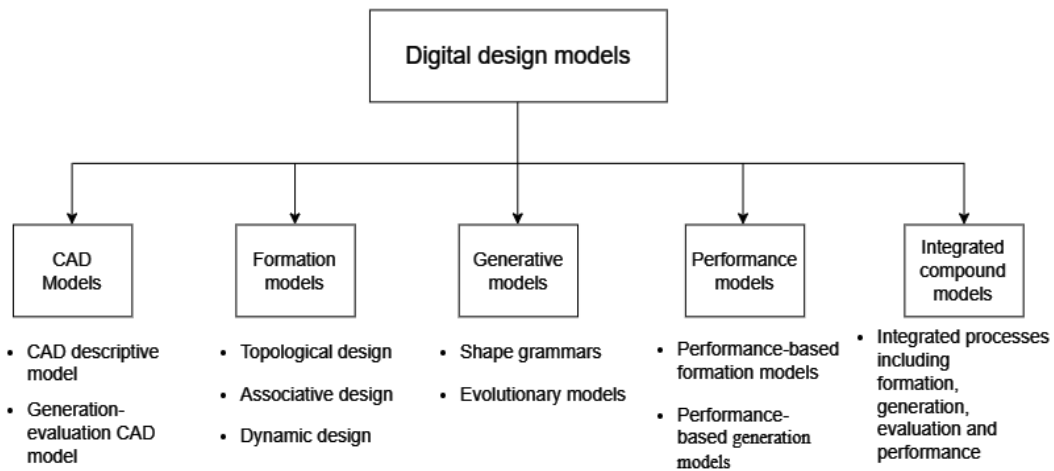


Figure 5: Computational design model based on Oxman [22]

2.1.5 The Integration of Computational Design Technology in Architectural Curriculum

In recent years, there has been a significant acceleration in integrating computational design technology within architectural design education. This incorporation marked the onset of a novel research domain in architectural education, first presented at the conference of the Education and Research in Computer-Aided Architectural Design in Europe (eCAADe) in 1983 [61].

In architectural design education, it is crucial to adopt cutting-edge technologies consistently. This incorporation ensures that students are adequately prepared to tackle the challenges caused by contemporary architecture and nurtures their ability to generate inventive and sustainable design solutions by utilizing advanced technologies.

Along with this paradigmatic shift in architectural design via computational design technologies, architectural education has been involved in the challenge of

adopting these technologies in its architectural design curricula. Since the late 80s and with the release of one of the pioneer works *The Electronic Design Studio* in 1989 [90], there has been a significant increase in the popularity of the research that is dedicated to exploring the implementation of computational design technology in architectural education. For instance, Gross & Do [90] presented six distinct models for 'digital design studios': The CAD-Plus Studio, The CAD Studio, The Intelligent Buildings Studio, The Virtual and Web Design Studio, The Cyberspace Design Studio, and The Tools and Toys Studio. These studios encouraged students to move beyond traditional computer usage in design and explore the latent power of various computational design tools.

Crafted by Celani [8], [24], her thesis and article aimed to instill in design students the perspective of Computer-Aided Design (CAD) as a 'design partner,' and a tool for 'augmenting' the design process. The primary aim was to unlock the inherent latent capabilities of the computer for effective utilization in the architecture design education field. She outlined an innovative design education system implemented at two distinct architecture schools in Brazil, adopting different approaches to Computer-Aided Design (CAD) utilization. The experimental courses aimed to achieve two primary goals: (1) to explore the application of logical operations in design, such as symmetry, recursion, parameterization, and combinatorial analysis, and (2) to apply these techniques through computer-aided design tools. The emphasis was not merely on using CAD as a representational tool but as an exploratory, customizable, and programmable design aid for the creative design process. The outcomes of these experiments included a diverse number of interesting compositions and design projects.

Angulo [91] presented a collection of case studies conducted in the Department of Architecture at Texas A&M University focused on addressing the integration of digital media in schools of architectural design. The case studies were organized around three main themes: understanding the role of digital media in design, integrating digital media in the design studio, and adjusting to the presence of emerging technologies.

In her article Oxman [77] investigated the recent developments in the architectural field, design theory, and digital design, emphasizing their relations to architectural design pedagogy. She discussed the evolution of digital design knowledge in architectural theory and practice, highlighting their implications on design education. An experimental design studio, focused on "Design as research: the exploration of digital architectural concepts," was presented as a pedagogical exemplify the digital educational approach.

Duarte et al. [92] conducted two case studies, the first in Portugal and the other in Brazil, regarding integrating computational design methods into the undergraduate architectural design curriculum. The IST program in Portugal offered several computer courses and labs, introducing diverse digital technologies including generative, evaluative, formative, and performance-based techniques. The Unicamp program in Brazil integrated mandatory courses such as computer graphics, animation, modeling, BIM, and elective courses such as rapid prototyping, design automation, digital fabrication, CAD programming, and generative design systems into the undergraduate curriculum.

Lecourtois and Guena [93] delineated an innovative pedagogical approach implemented at the School of Architecture of Paris La-Villette to equip aspiring

students with the essential skills for engaging with parametric design. Diverging from most conventional parametric design studios, they emphasized a methodology that empowers students to find out their unique design approaches through a comprehensive understanding of parametric design.

Stavric et al. [94] presented a revamped syllabus for the "Methods of Representation" course that responded to the fast-paced technological advancements in architectural design, emphasizing the importance of combining digital and analog methods. Students engaged in various activities such as studying complex geometries and analyzing organic forms through manual drawing. The course covered collaborative peer-to-peer work on a web interface, NURBS-modeling, and rapid prototyping.

In another paper by Mark et al. [95] they emphasized the importance of keeping the traditional courses within the design curriculum while inserting computer technology into the curriculum. They proposed 'the ideal computer curriculum, 'highlighting the importance of integrating computation technology without displacing traditional subjects. This can be achieved by gradual integration of these technologies into existing courses. The paper established a framework for architectural design education programs and curricula applicable for professional use in design schools.

Riekstins [96] shed light on a paradigm shift from software-centric learning to a more comprehensive understanding of design possibilities and problem-solving. The article emphasized the importance of digital design literacy that extends beyond proficiency in specific computers and focuses on finding ways to create customized tools for design problem-solving. This proficiency in digital design prepares students to

harmoniously incorporate advanced workflows into design studios, thereby giving them latitude for the expression of their inventive abilities.

Rokicki and Stefanska [97] discussed the emergence of parametric and generative design as powerful directions in modern architecture, facilitated by computer-aided design. The paper focused on the analysis of small-sized pavilions done by students at the Faculty of Architecture at Warsaw University of Technology, revealing how their scale allows architects to address particular design problems and look for solutions, leading to innovative and buildable structures.

Xiang et al. [97] focused on developing a sustainable model for introducing and teaching digital design based on qualitative data from 15 universities in China. An analysis of teaching models in these institutions led to the creation of a "comprehensive model of digital architectural design teaching." This model aligns and meets with contemporary digital architectural design education standards and serves as a foundational framework for establishing better architectural design curricula.

Furthermore, numerous researchers showcased case studies and experiments concerned with integrating different topics of computational design technology within the architectural design curriculum. For instance, various studies delved into teaching architecture students computational design thinking [20], [22], [50], [75], [98]- [103] other studies focused on introducing and training students to use parametric design [9], [89], [93], [96], [100], [104]-[109], algorithmic design [69], [97], [99], [110]-[112] and generative design [7], [22], [77], [84], [113]-[117] in their design projects.

Other key researchers advocate the importance of scripting and tool-making to be part of design education [10], [67], [118], [119].

Furthermore, other articles went beyond exploiting computational design technology within the design phase but instead introduced Computer-Aided Manufacturing (CAM), prototyping, and fabrication techniques to the students [82], [120]-[127].

Within the Turkish context, several endeavors by researchers and educators have contributed to narrowing the gap between computational design technology and architectural design education. For example, Yalınay-Çinici et al. [17] presented a design research studio to reinforce logical thinking skills and introduce parametric design modeling to graduate students. Another study by Acıcan [21] explored a contemporary teaching approach inspired by the Smartgeometry Organization for teaching computational design to architecture students. She adopted their computational design teaching model that focused on introducing concepts related to computational design tools and methods. Agirbas [11], [12], [128] conducted several case studies involving the implementation of courses and workshops designed to teach parametric design through visual programming to undergraduate architectural design students.

Moreover, many Turkish researchers presented case studies and experiments focused on incorporating various aspects of computational design technology into the architectural design curriculum. Examples include studies that explored instructing architecture students in computational design thinking [5], [14], [16], [64], [129]-[132]. Other case studies delved into teaching architectural students shape grammar as an established paradigm that applies a set of shape rules to analyze and describe generated designs [19], [70], [133]-[140].

Other efforts were made to integrate parametric design [253], generative design [18], [141], [142], and algorithmic design [143] into the design curriculum.

In addition, several endeavors were conducted to incorporate other topics from computational design technology such as visual scripting [11], [12], [128], [144], [145], simulation and optimization techniques [13], [15], [146], [147]-[149], and fabrication techniques [150]-[154] within the architectural design curriculum.

The circumstances of computational design technology adoptions in architectural design curricula had noticeable effects on students' behavior toward using computational design technology. Several researchers focused on evaluating design students' behavior from different aspects. For instance, some researchers assessed students' behavior in terms of decision-making during design activities [25], [47], [155]-[157]. Other various scholars concentrated on assessing design students' attitudes [8], [23], [24], [26], [31], [32], [49], [51], [128], [52], [158] and self-efficacy [159] toward using different types of tools and computer software in their design projects. Other researchers focused on evaluating the perceptions of design students towards various types of tools [28], [29], [30], [33], [160]. Other scholars evaluate the behavior of design students from other perspectives, for instance studying users' preference in choosing software packages for the design process [161], [162] and user satisfaction in utilizing certain computer software such as computer-aided design (CAD) packages [27], [38], [163].

2.2 The Unified Theory of Acceptance and Use of Technology

Several theories and models were developed to evaluate individual's behavior toward adopting and using technology. Such theories have roots in sociology, psychology, and information systems fields in which the behavior of the users toward technology is explained [37], as shown in (Table 1).

Table 1: Summary of models and theories involved in UTATU

Theory/Model	Developer and year	Field of development
Innovation Diffusion Theory (IDT)	Everett Roger, 1962 [37].	Sociology
Theory Of Reasoned Action (TRA)	Fishbein And Ajzen, 1967 [34].	Social Psychology
Theory Of Planned Behavior (TPB)	Ajzen, 1985 [164].	Social Psychology
Technology Acceptance Model (Tam)	Fred. D. Davis, 1986 [35].	Information Systems
Combined-TAM-TPB (C-TAM-TPB)	Taylor And Todd, 1995a [165].	Information Systems
Motivational Model (Mm)	Davis, Bagozzi, And Warshaw, 1992 [166].	Psychology
Model Of Personal Computer Utilization (MPCU)	Thompson, Higgins, And Howell, 1991 [167].	Information Systems
Social Cognitive Theory (Sct)	Bandura, 1986 [168].	Psychology

Innovation Diffusion Theory (IDT)

The theory of Innovation Diffusion Theory (IDT) by Everett Roger 1962 [37], has been used to study the process of adopting the technology/innovation by the users by identifying the innovation attributes that persuade an individual to adopt the innovation such as (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability that affects the rate of the adoption of the technology by its users [36]. Kale and Arditı [169] applied IDT theory in studying the factors that influence the diffusion of Computer-aided design (CAD) technology in the Turkish architectural design practice (Figure 6).

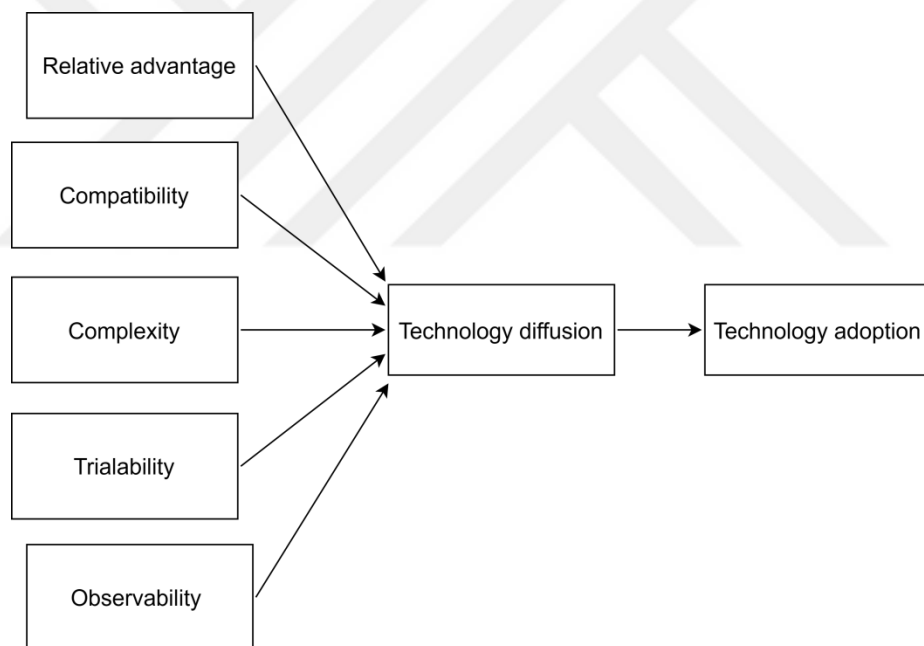


Figure 6: Innovation Diffusion Theory (IDT) model

Theory of Reasoned Action (TRA)

Another theory, adopted from social psychology, the Theory of Reasoned Action (TRA) developed by Fishbein and Ajzen in 1967, one of the early attempts to understand the factors that influence human behavior, identifies that a performance of a certain behavior is influenced by the individual's attitude and the subjective norms [34].

Subjective norm refers to the person's perception of whether important individuals around him/her believe they should or should not perform the behavior in question [34]. Ding et al. [170] studied architects' behavior toward adopting building information modeling software (BIM) in practice based on the theory of reasoned action [170] (Figure 7).

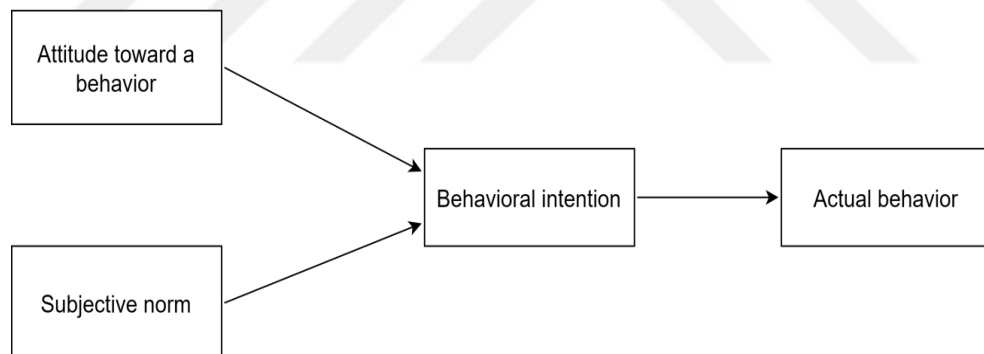


Figure 7: Theory of Reasoned Action (TRA) model

Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB) formulated by Ajzen in 1985 is an extension of the theory of reasoned action (TRA). Since the theory of reasoned action did not cover

an individual's perceived self-ability, Ajzen developed the theory of planned behavior by including perceived behavioral control as a determinant of the user's behavioral intention which in sequence influences their behavior. Other determinants are the individual's attitude and the subjective norms [164] (Figure 8).

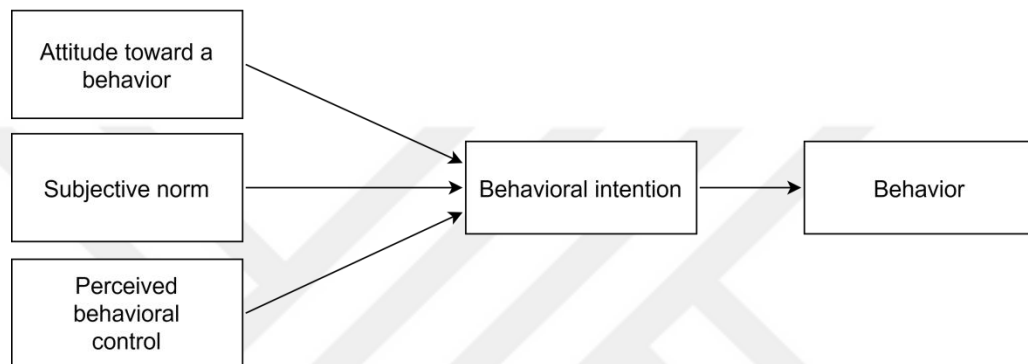


Figure 8: Theory of Planned Behavior (TPB) model

Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) developed by Fred. D. Davis in 1986, which is adopted from information systems theory, focuses on the technology contexts itself such as computer-based information systems. In the TAM, perceived usefulness and perceived ease of use of a system affect users' acceptance of the system [35]. TAM2 extended TAM by incorporating subjective norm as an additional predictor of intention [171]. Guray and Kismet [48] developed a survey based on (TAM) to evaluate architecture student's acceptance and behavioral intention to use the new digitalization model (DM) that integrates building information modeling software (BIM) and augmented reality technologies (AR) in "building construction project" in an architectural design course (Figure 9).

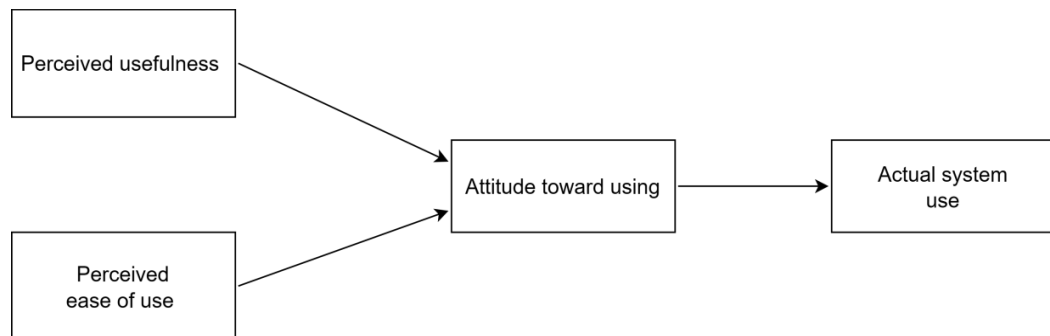


Figure 9: Technology Acceptance Model (TAM) model

Combined-TAM-TPB (C-TAM-TPB)

In addition, a hybrid model by Taylor and Todd formulated in 1995 [165] combining two theories Technology Acceptance Model (TAM) and Theory of Planned Behavior (TPB): Combined-TAM-TPB. They developed a mixed model that merges constructs from TAM and TPB. The resulting model C-TAM-TPB offered a high level of compatibility for explaining user adoption of new technology (Figure 10).

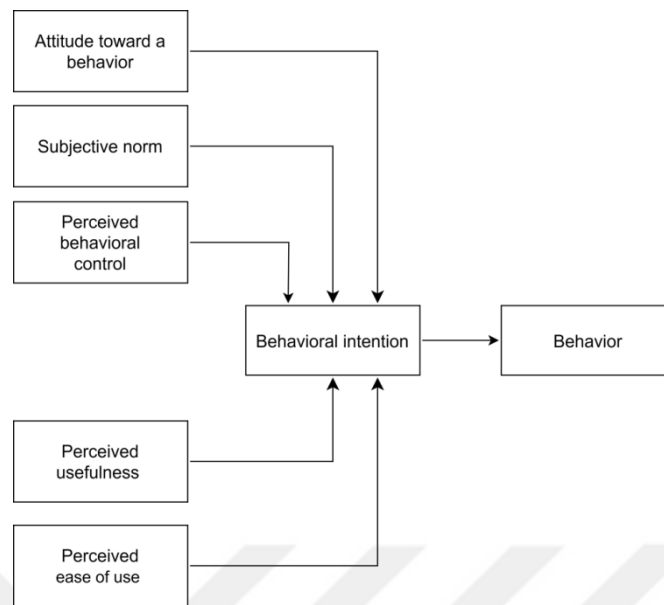


Figure 10: Combined-TAM-TPB (C-TAM-TPB) model

Motivational Model (MM)

Another model from psychology is the Motivational Model (MM) introduced by Davis, Bagozzi, and Warshaw in 1992. This model posits that extrinsic and intrinsic motivation plays an important role in influencing a user's intention to engage in a particular behavior that leads the user to engage in the actual behavior [166]. Extrinsic motivation and intrinsic motivation refer to the external factors and internal factors respectively that motivate the user to perform a particular behavior. An example of extrinsic motivation is users' perception that utilizing computer software will enhance their work performance. While intrinsic motivation is the user's degree of enjoyment derived from using the software (Figure 11).

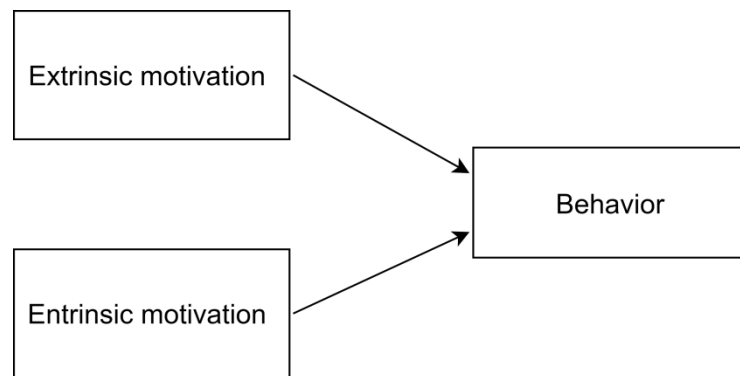


Figure 11: Motivational Model (MM) model

Model of Personal Computer Utilization (MPCU)

The Model of Personal Computer Utilization (MPCU) was developed by Thompson, Higgins, and Howell in 1991. This model is concerned with studying individual acceptance and use (usage behavior) of different types of information technologies. MPCU core constructs are job fit, complexity, long-term consequences, effect towards use, social factors, and facilitating conditions [167] (Figure 12).

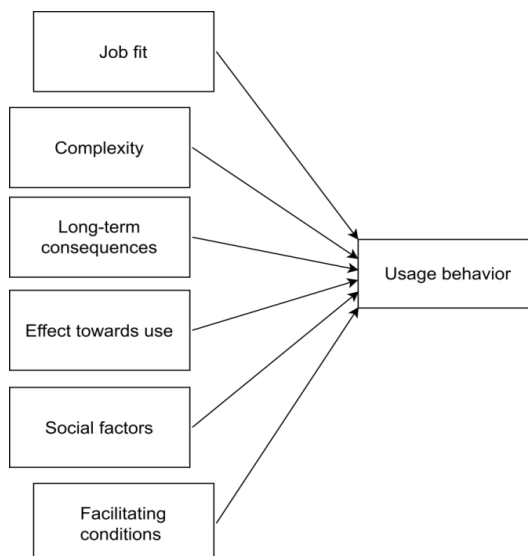


Figure 12: Model of Personal Computer Utilization (MPCU) model

Social Cognitive Theory (SCT)

Compeau and Higgins [172] applied the Social Cognitive Theory (SCT) -one of the most powerful theories that explain human behavior developed by Bandura in 1986 [168] - in the computer utilization context. They employed (SCT) to study the individual's usage of the computer based on 5 constructs: outcome expectations-performance, outcome expectations- personal, self-efficacy, affect, and anxiety (Figure 13).

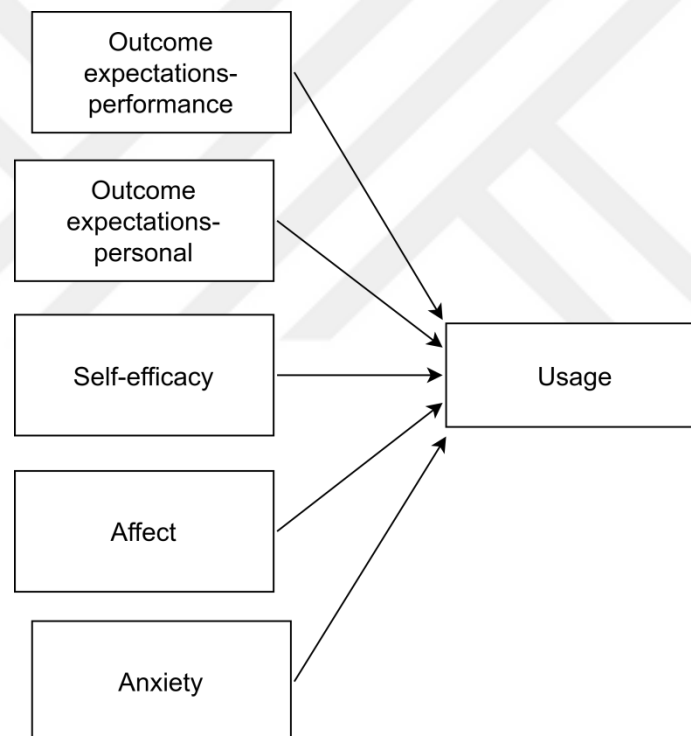


Figure 13: Social Cognitive Theory (SCT) model

Each of these models and theories has different sets of technology acceptance determinants that evaluate to which extent a user is accepting and using technology [37]. These theories have delved into analyzing individual's behavior toward using new technologies. But each theory and model has its limitations for instance Qingfei et al.

[173] discussed that no theory comprehensively addresses all behavioral factors. Researchers of “technology acceptance and usage behavior” are confronted with choosing the most appropriate theory/model or opting to combine multiple theories/models for their research. Gradually these eight theories and models were comprehensively revised, synthesized, and developed leading to the formulation of a new holistic model called the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh, Morris, Davis, and Davis [37] (Figure 14). This model is one of the latest developed models in the technology acceptance study domain. It is a unified model that combines and benefits from all the old, well-known models to present a more complete picture of understanding an individual’s behavior toward a technology.

Thus, this model considers progress in finding a unified evaluation tool that assesses the factors that affect usage behavior and acceptance of new technology [37]. UTAUT is a robust foundation to predict the diffusion of technology and a tool to assess the degree of success of technology by understanding the factors and drivers that lead to the acceptance of technology among users. [37], [39], [40].

It evaluates users’ behavioral intention to use the system and their usage behavior while using the system from a holistic view as it successfully combines variables from previous theories and models into a unified model (Figure 15). Thirty-two (32) determinants from the previous theories were synthesized into seven direct and indirect determinants that evaluate user attributes, technology attributes, and social attributes, hence, this model becomes a holistic model in studying the determinants that affect user behavior toward technology. It is important to note that in UTAUT model “indirect” indicates that there is no influence on behavioral intentions. [37], [55].

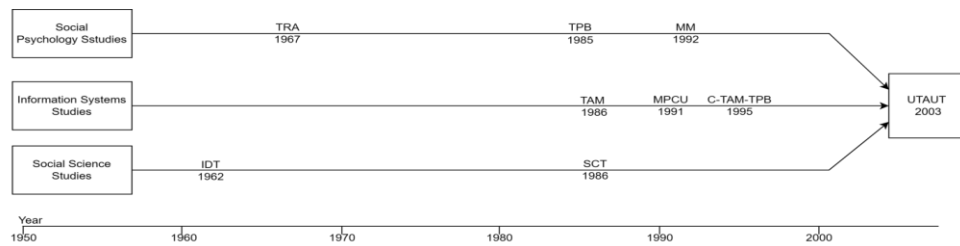


Figure 14: Chronological graph for the evolution of technology acceptance theories that led to the formation of the UTAUT model. Developed by the author based on Momani and Jamous [174].

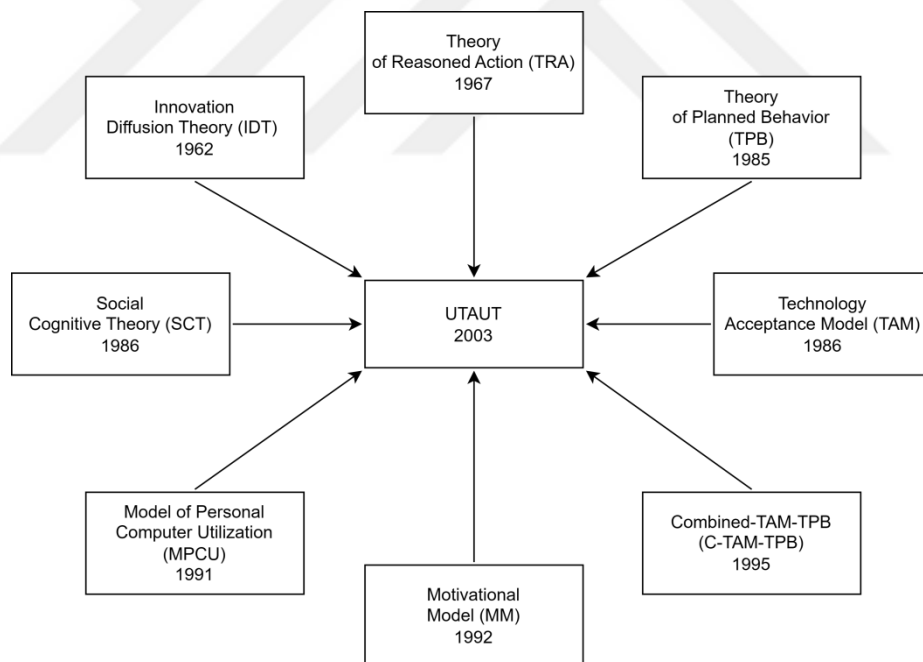


Figure 15: Holistic view of UTAUT

2.2.1 The Determinants and Moderators of the Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. [37] classified seven determinants of the UTAUT model: four direct determinants namely, (1) performance expectancy, (2) effort expectancy, (3) social influence, and (4) facilitating conditions, and three indirect (no influence) determinants (1) attitude, (2) self-efficacy, and (3) anxiety (Table 2). These determinants are related to predicting behavioral intention and usage behavior of technology in organizational contexts. There are four moderators age, voluntariness, and experience. The four direct determinants and the three indirect (no influence) determinants are described below:

Direct determinants:

The UTAUT model identifies four direct determinants crucial to understanding user acceptance of technology: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. These elements delve into users' beliefs, perceptions of ease, social influences, and organizational support, providing a comprehensive framework for technology adoption.

a. Performance Expectancy

Performance expectancy is defined as the degree to which users believe that utilizing the system will help them achieve gains in job performance. Performance expectancy determinant finds its roots in five constructs models from different models: perceived usefulness from TAM/TAM2 and combined-TAM-TPB, relative advantage from IDT, extrinsic motivation from MM, job-fit from MPCU, and outcome expectations from SCT [37].

b. Effort Expectancy

Effort expectancy refers to the degree of ease associated with the use of the system. Performance expectancy determinant is formulated from three constructs from different models: perceived ease of use from TAM/TAM2, complexity from MPCU, and ease of use from IDT [37].

c. Social Influence

Social influence is defined as the degree to which a user perceives that important others (e.g., colleagues and friends) believe he or she should use the new system. The social influence determinant is the combination of three constructs from three models: social factors in MPCU, the subjective norm in TRA, TAM2, TPB, and combined-TAM-TPB, and image in IDT [37].

d. Facilitating Conditions

Facilitating Conditions refer to the extent to which a user believes that an organizational and technical infrastructure exists to support the use of the system. This determinant finds its root in perceived behavioral control from TPB and combined-TAM-TPB, compatibility from IDT, and facilitating conditions from MPCU [37].

Indirect determinants (no influence):

Indirect determinants in the UTAUT model, which exhibit no influence on technology acceptance, include Attitude, Self-Efficacy, and Anxiety. These factors gauge users' affective reactions, perceived abilities, and emotional responses but do not impact their adoption of technology.

a. Attitude

Attitude toward using technology is defined as the user's overall affective reaction to using a system. This determinant is formulated from four constructs: intrinsic motivation from MM, attitude toward behavior from (TRA, TPB, combined-TAM-TPB), affect from SCT, and affect toward use from MPCU [37].

b. Self-Efficacy

Self-efficacy is defined as the judgment of an individual's ability to use a technology or information system to accomplish a particular job or task. This indirect determinant is adopted from social cognitive theory (SCT) [37].

c. Anxiety

Anxiety refers to the trigger of anxious or emotional reactions when performing a behavior, such as using a computer. This indirect determinant is adopted from social cognitive theory (SCT) [37].

Table 2: UTAUT constructs

Construct	Correspondence	Theory/ Model	Source
Performance Expectancy	Perceived usefulness	TAM/TAM2 and C-TAM-TPB	Davis 1989 [175]; Davis et al. 1989 [176].
	Relative advantage	IDT	Moore and Benbasat 1991 [177]; Rogers, 1962 [36].
	Extrinsic motivation	MM	Davis et al. 1992 [166].
	Job-fit	MPCU	Thompson et al. 1991 [167].

	Outcome expectations	SCT	Bandura 1986 [168]; Compeau and Higgins 1995b [172]; Compeau et al. 1999 [178].
Effort Expectancy	Perceived ease of use	TAM/TAM2	Davis 1989 [175]; Davis et al. 1989 [176].
	Complexity	MPCU	Thompson et al. 1991 [167].
	Ease of use	IDT	Moore and Benbasat 1991 [177]; Rogers, 1962 [36].
Social influence	Social factors	MPCU	Thompson et al. 1991 [167].
	Subjective norm	TRA, TAM2, TPB and C-TAM-TPB	Ajzen 1991 [179]; Davis et al. 1989 [176]; Fishbein and Ajzen 1975 [34]; Taylor and Todd 1995b [180]
	Image	IDT	Moore and Benbasat 1991[177]; Rogers, 1962 [36].
Facilitating Conditions	Perceived behavioral control	TPB and C-TAM-TPB	Ajzen 1991; [179] Taylor and Todd 1995a [165], 1995b [180].
	Compatibility	IDT	Moore and Benbasat 1991[177]; Rogers, 1962 [36].
	Facilitating conditions	MPCU	Thompson et al. 1991 [167].
Attitude toward using technology	Intrinsic motivation	MM	Davis et al. 1992 [181].
	Attitude toward behavior	TRA, TPB, C-TAM-TPB	Davis et al. 1989 [176]; Fishbein and Ajzen 1975[34]; Taylor and Todd 1995a [165].
	Affect	SCT	Bandura 1986 [182]; [172]; Compeau et al. 1999 [178].
	Affect toward use	MPCU	Thompson et al. 1991 [167].
Self-efficacy	Self-efficacy	SCT	Bandura 1986 [182]; Compeau and Higgins 1995b [172]; 1995a [183].
Anxiety	Anxiety	SCT	(Bandura 1986 [182].

2.2.2 Behavioral Intentions and Usage Behavior

In UTAUT model, “behavioral intention” refers to user’s perceived likelihood to engage in a given behavior [35], [184]. The behavioral intention was measured through self-assessment of a three-item scale adopted from Davis et al. [176]. While regarding “Usage behavior”, it represents the individual acceptance and use of technology. It was measured by assessing the user usage duration of the system via system logs. Venkatesh et al. [37] presented that the usage behavior of the individual is determined by their behavioral intention (Figure 16).

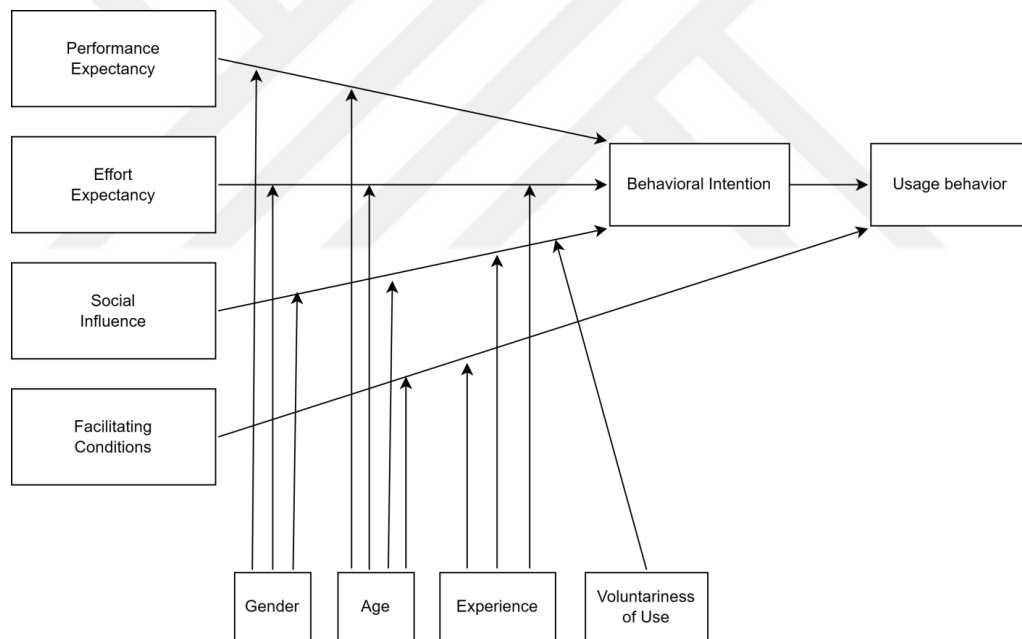


Figure 16: UTAUT model

The UTAUT model was used as a foundation by many researchers to conduct studies related to user acceptance of information technology and software in different domains, for instance, researchers have applied, integrated, and extended UTAUT [55] in various settings (different user types, different organization types, different tasks,

different times, different locations and different types of technologies). Technology users can be categorized into different groups such as students, employees, citizens, and consumers. For instance, Wrycza et al [185] utilized the UTAUT model to evaluate students' acceptance of software engineering tools within Information Systems Development courses. Mustafa et al. [186] studied the "consumer's" intention of adoption of e-commerce in developing countries. Sani et al. [187] research focused on studying the factors that affect government practitioners in adopting Big Data Analytics. Other studies targeted a wider sample of technology users as Dwivedi et al. [188] studied the adoption of mobile health services by citizens of from three countries: the USA, Canada, and Bangladesh. Other studies targeted more specific samples such as students as Sarfraz et al. [189] studied students' views and preferences for blended learning which replaced face-to-face learning after the COVID-19 pandemic. UTAUT was also adopted in the research that targeted different types of organizations such as schools [189], [190], universities [191], [192], hospitals [193], [194], government organizations [41], [55], [195], and construction firms [196]-[198].

Furthermore, the model was also applied on different types of tasks such as filing of income tax [199], different times as Venkatesh et al. [200] studied the initial use and post-adoptive use of mobile banking, and different locations [187], [188]. Acceptances of various types of technology were also studied by applying UTAUT model. For instance, Williams et al. [201] examined over 98 articles that studied different types of information systems such as Mobile Banking, Robot System, Web-based Virtual M-Learning System, Human-Computer Interaction Tool, Computer Graphics Technology [201], [202].

2.2.3 Studies on Computational Design Technology Based on the Unified Theory of Acceptance and Use of Technology (UTAUT)

In parallel with design students' increased exploitation of computational design technology in the architectural design education domain, a study on the students' behavior toward computational design technology has come into prominence. As for a technology to improve productivity and for students to use it efficiently in their studies as well as in practice, it should be accepted in the first place by its users by developing positive behaviors towards it [37]. Evaluating users' behavior toward acceptance of technology is one of the mature research areas in contemporary information systems research [37].

Nevertheless, by reviewing the existing literature, it is found that the studies that examine the acceptance of computational design technology by students are limited. Several studies were found on evaluating architects' and engineers' acceptance and use of computational design technology -approaches, techniques, and tools- in the architecture and construction domain, such as Building Information Modeling (BIM) [40], [169], [196]- [198], [203]-[211] while, few studies focused on evaluating students' acceptance of computational design technology in architectural education [38], [44], [47], [48]. Due to the limited computational design technology users' evaluative research, particularly concerned with CD tools acceptance and use by architecture design students, the gap of this research has been identified as this research examines and evaluates the behavior and patterns of use of computational design tools by fourth-

year architectural design students in the Department of Architecture at Ozyegin University in Turkey.



CHAPTER III

RESEARCH MODEL AND HYPOTHESIS

Based on the literature review introduced in the preceding chapter, a research model and research hypotheses are presented in this chapter. The studied factors are Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Attitude, Anxiety, and Self-efficacy. This chapter discusses these factors in detail and a proposal for the hypotheses.

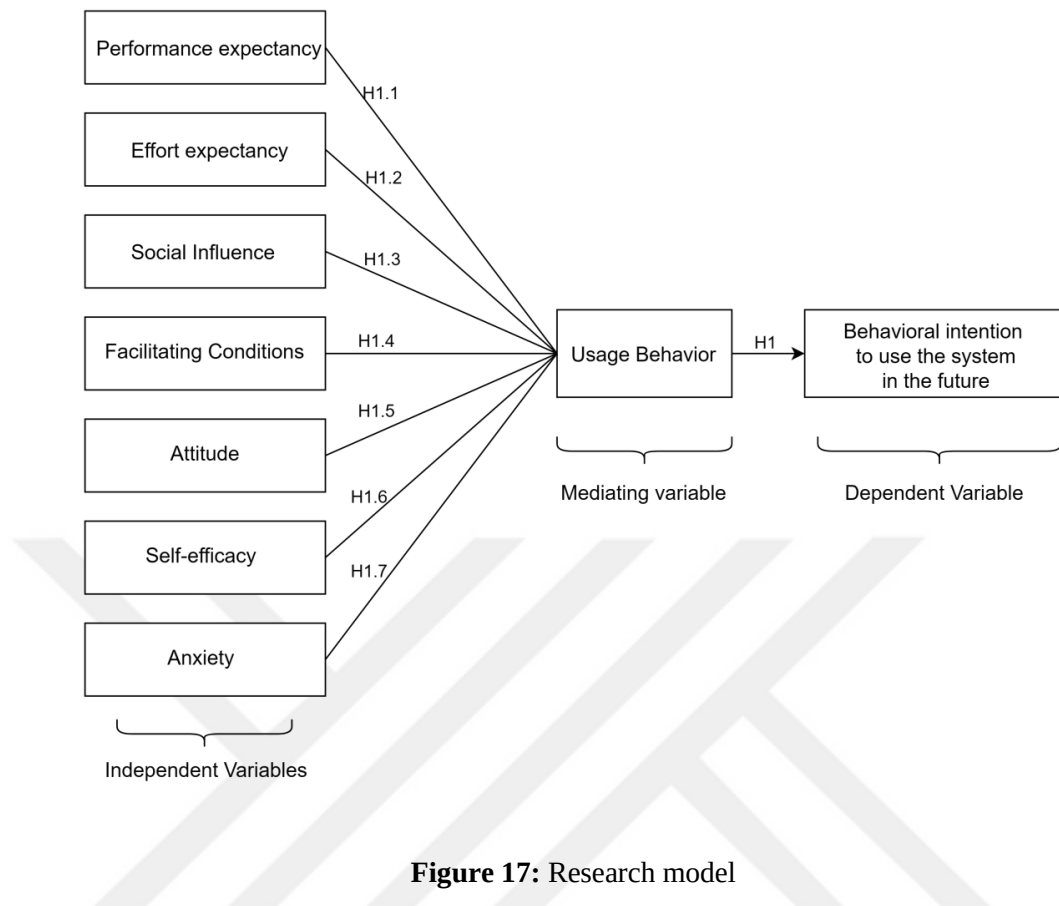
3.1 Research Model Development

The research model proposed in this study is a modification of the UTAUT model in the context of computational design technology in architectural education. Several studies modified and extended the UTAUT model in different contexts as was elaborated in Chapter 2 [37], [39], while other studies extended the model and utilized it in architectural and engineering contexts [40], [204], [209].

The original UTAUT model, as explained in Chapter 2, is based on seven determinants (four direct determinants: performance expectancy, effort expectancy, social influence, and facilitating conditions and three indirect determinants: attitude, self-efficacy, and anxiety) that influence user's behavioral intention and usage behavior towards an information system. Four moderators, such as gender, age, voluntariness, and experience, were found to have a significant effect on the relationship between the determinants (independent variables) and the behavioral intention and usage behavior (dependent variable) [37].

The UTAUT model proposes that behavioral intention is a predictor of usage behavior. This means that behavioral intention is an independent variable and usage behavior is the dependent variable. Behavioral intention refers to an individual's perceived intention to perform the behavior, and usage behavior represents the user's acceptance and use of the technology [37]. Much precedent research found a significant relationship between behavioral intention and usage behavior [37], [166], [175], [212], [213].

The research model of this thesis is a modification of the UTAUT model and is presented in Figure 17. In our proposed modified UTAUT model, usage behavior is determined to be the mediating variable, and behavioral intention is determined to be the dependent variable. The reason behind this modification is that in the context of this research, students must use the system (specific types of computational design tools) in their design projects. Therefore intentions do not affect their usage behavior. However, their usage behavior might influence their intentions to use the tools after they graduate as it will be discussed in the next section. This is the reason why these two variables were reversed.



3.2 Main hypothesis of the research:

The main hypothesis of this research was formulated to evaluate the influence of students' usage behavior (UB) on their behavioral intentions (BI) to use the CD tool in architectural practice.

H1: Positive usage behavior towards computational design tools will positively influence students' behavioral intention to use the tools in the architecture practice after graduation.

In this context, usage behavior acts as a mediating variable. The Mediating variable is prominent in psychological theory and research [214]. It transmits the effect of the independent variable on the dependent variable.

In the current research model, usage behavior is the mediating variable. It refers to the patterns and ways students tend to use computational design tools in their design projects. Students today commonly use computational design tools in their design projects in architecture design education. Usually, they learn about these tools in their second year and get their experience during their bachelor's degree. At this point (when the research was conducted), it is confirmed that final-year architectural design students have had some experience using computational design tools, this research argues that it would influence their usage behavior. Thus, this research expects that architecture design students' usage behavior towards computational design tools will affect-their intention to use these tools after graduation. Usage behavior will be measured through self-assessment -of the current usage- of a five-item scale adopted from [157].

In the proposed modified UTAUT model, behavioral intention is determined to be the dependent variable. It represents architectural design students' intention and likelihood to use computational design tools in the future –post-graduation-. The current proposed model expects that students' behavioral intention to use computational design tools in the future is linked to their usage behavior during their bachelor's. The behavioral intention will be measured through self-assessment -of future usage- of a five-item scale adopted from [37], [215].

3.3 *Determinants Influencing Students' Usage Behavior toward Computational Design Tools*

Research hypotheses were formulated according to the research objectives and based on the UTAUT model. The ultimate goal of this thesis is to evaluate the behavioral, technological, and environmental factors that influence architecture design students' usage behavior, which in sequence affect their behavioral intentions to use the system in the future. Seven determinants/factors are examined as independent variables (performance expectancy, effort expectancy, social influence, facilitating conditions, attitude, self-efficacy, and anxiety). Behavioral intention is the determinant to be the mediating variable and behavioral intention is the dependent variable. Figures 18 and 19 show the grouping of these determinants and questionnaire items included under each determinant.

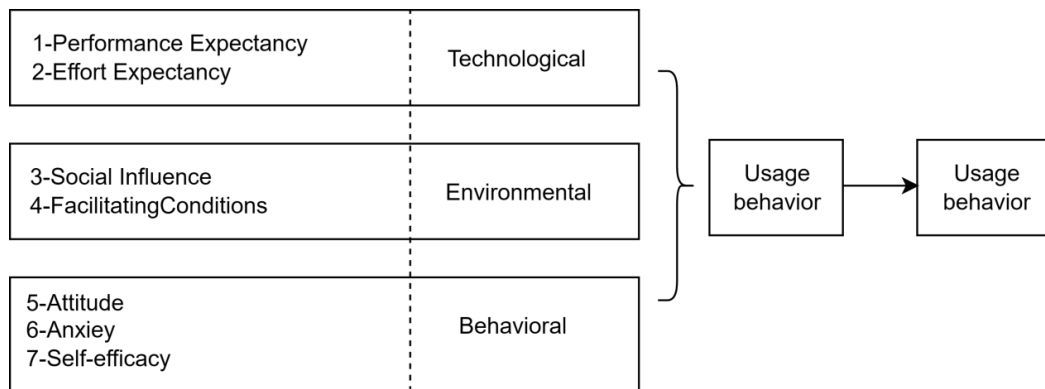


Figure 18: Classifications of usage behavior determinants

The Unified Theory of Acceptance and Use (UTAUT)							
Technological determinants	<table> <tr> <td>1- Performance Expectancy</td><td> 1- I would find using CD tools useful in my design projects. 2- Using CD tools enable me to accomplish my design task more quickly. 3- Using CD Tools increase my productivity. 4- By using CD tools, I will increase my chances of coming up with better/ more creative designs. 5- The use of CD tools consumes less time compared to conventional design tools. 6- Using CD tools give me greater control over my design. 7-Using CD tools in curriculum design projects have improved my architectural design skills compared with traditional tools. </td></tr> <tr> <td>2-Effort Expectancy</td><td> 8- CD Tools are clear and understandable. 9- It is easy for me to become skillful at using CD tools. 10- I find CD tools easy to use in my curriculum design projects. 11- I learned how to use CD tools quickly. 12- I would find CD tools to be flexible to use. 13- It is easy for me to remember how to perform tasks using CD tools. </td></tr> </table>	1- Performance Expectancy	1- I would find using CD tools useful in my design projects. 2- Using CD tools enable me to accomplish my design task more quickly. 3- Using CD Tools increase my productivity. 4- By using CD tools, I will increase my chances of coming up with better/ more creative designs. 5- The use of CD tools consumes less time compared to conventional design tools. 6- Using CD tools give me greater control over my design. 7-Using CD tools in curriculum design projects have improved my architectural design skills compared with traditional tools.	2-Effort Expectancy	8- CD Tools are clear and understandable. 9- It is easy for me to become skillful at using CD tools. 10- I find CD tools easy to use in my curriculum design projects. 11- I learned how to use CD tools quickly. 12- I would find CD tools to be flexible to use. 13- It is easy for me to remember how to perform tasks using CD tools.		
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Environmental determinants	<table> <tr> <td>3- Social Influence</td><td> 14- I use CD Tools because I got influenced from the students around me. 15- The studio master in design course has been helpful in encouraging the use of CD tools. 16- The social environment of the studio has supported the use of CD tools. 17- I feel pressured to use CD tools in design projects because everyone uses them. 18- Students in studio who use CD tools have more prestige than those who do not. </td></tr> <tr> <td>4- Facilitating Conditions</td><td> 19- I have the necessary resources to use CD tools. 20- I have learned and trained with the necessary knowledge to use CD tools. 21- Guidance from a specific person or group was available to me to assist me with CD tools difficulties. 22- As a final-year student, I think that the period of previous semesters was enough to learn using CD tools professionally. 23- As a final-year student, I think that the period of previous semesters were enough to gain an intermediate level of using CD tools. </td></tr> </table>	3- Social Influence	14- I use CD Tools because I got influenced from the students around me. 15- The studio master in design course has been helpful in encouraging the use of CD tools. 16- The social environment of the studio has supported the use of CD tools. 17- I feel pressured to use CD tools in design projects because everyone uses them. 18- Students in studio who use CD tools have more prestige than those who do not.	4- Facilitating Conditions	19- I have the necessary resources to use CD tools. 20- I have learned and trained with the necessary knowledge to use CD tools. 21- Guidance from a specific person or group was available to me to assist me with CD tools difficulties. 22- As a final-year student, I think that the period of previous semesters was enough to learn using CD tools professionally. 23- As a final-year student, I think that the period of previous semesters were enough to gain an intermediate level of using CD tools.		
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Behavioral determinants	<table> <tr> <td>5- Attitude</td><td> 24- CD tools make designing more interesting. 25- Designing with CD tools are fun and enjoyable. 26- I like using CD tools in my curriculum design projects. 27- When using CD tools I feel more confident with my design. 28- CD tools give me the courage and motivation to accomplish the design project. 29- I am satisfied with using CD tools in my design project. </td></tr> <tr> <td>6- Self-efficacy</td><td> 30- I can recover from mistakes quickly and easily while using CD tools. 31- I can solve most problems without someone around to tell me what to do as I go. 32- Whatever comes my way while using CD tools, I can find the solution without calling for assistance or access to support videos. 33- I believe I have enough knowledge on how to use CD tools in my curricular design projects. 34- I can use CD tools in my design projects with ease and proficiency. 35- I can complete a task using CD tools without asking for extra time. 36- When I am confronted with a problem, I can usually find several solutions. 37- When I design with CD tools I can easily achieve the desired design that I want. 38- I am confident that I could deal efficiently with unexpected events while using CD tools. </td></tr> <tr> <td>6- Anxiety</td><td> 39- As a final-year student I still feel anxious about using CD tools. 40- As a final-year student I still feel scared of doing mistakes while using CD tools. 41- As a final-year student I hesitate to use the system for fear of making mistakes I cannot correct. 42- I can't control my anxiety when I face an issue during the use of CD tools in my design project </td></tr> </table>	5- Attitude	24- CD tools make designing more interesting. 25- Designing with CD tools are fun and enjoyable. 26- I like using CD tools in my curriculum design projects. 27- When using CD tools I feel more confident with my design. 28- CD tools give me the courage and motivation to accomplish the design project. 29- I am satisfied with using CD tools in my design project.	6- Self-efficacy	30- I can recover from mistakes quickly and easily while using CD tools. 31- I can solve most problems without someone around to tell me what to do as I go. 32- Whatever comes my way while using CD tools, I can find the solution without calling for assistance or access to support videos. 33- I believe I have enough knowledge on how to use CD tools in my curricular design projects. 34- I can use CD tools in my design projects with ease and proficiency. 35- I can complete a task using CD tools without asking for extra time. 36- When I am confronted with a problem, I can usually find several solutions. 37- When I design with CD tools I can easily achieve the desired design that I want. 38- I am confident that I could deal efficiently with unexpected events while using CD tools.	6- Anxiety	39- As a final-year student I still feel anxious about using CD tools. 40- As a final-year student I still feel scared of doing mistakes while using CD tools. 41- As a final-year student I hesitate to use the system for fear of making mistakes I cannot correct. 42- I can't control my anxiety when I face an issue during the use of CD tools in my design project
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Figure 19: Questionnaire Items with classifications

Independent Variables

Introducing the independent variables of the UTAUT model, these factors play a crucial role in shaping users' behaviors and intentions to adopt a specific technology system.

The key variables and the formulated sub-hypotheses are introduced:

a. Performance Expectancy

The extent to which a user believes that utilizing a technology system will contribute to attaining gains in their job performance [37]. Several researches have revealed that performance expectancy has a strong influence on user adoption, behavior, and intentions to use a certain technology system [216], [217], [218], [219], [220]. However, a study by Howard et al. [40] found a weak relationship between performance expectancy and behavioral intentions in using Building Information Modeling (BIM) in the construction industry.

Performance expectancy corresponds to perceived usefulness in (TAM/TAM2 and C-TAM-TPB). Perceived usefulness is the degree to which an individual believes that using a system will improve their job performance [175]. Perceived usefulness strongly influences the actual system use [175]. This research intends to find the relationship between “performance expectancy” factor and usage behavior which in turn influences behavioral intentions. This research assumes that if students perceive using computational design tools is easy, they are more likely to develop a positive usage behavior toward the tools. This leads to the following hypothesis:

H1.1: Performance expectancy will positively affect students’ usage behavior towards using computational design tools.

b. Effort Expectancy

Effort expectancy refers to the degree of ease associated with the use of the system [37]. Effort expectancy is one of the key constructs in the UTAUT model that influences behavioral intention and in sequence affects usage behavior. The construct effort expectancy corresponds to the perceived ease of use in TAM [175]. Perceived ease of use is defined as the user's belief that using a certain technology system is easy [175]. Several studies revealed that effort expectancy has a significant influence on system usage [221], [218], [222], [223], \ [224]. However, Al-Gahtani & Hubona [225] and Zhou & Wang [227] found in their research that effort expectancy has no direct influence on the usage behavior of a technology system. Thus, this thesis assumes if design students perceive that using computational design tools is easy, they are more likely to develop a positive usage behavior toward the tools. This leads to the following hypothesis:

H1.2: Effort expectancy will positively affect students' usage behavior towards using computational design tools.

c. Social Influence

Social influence is defined as the degree to which a user perceives that important others (e.g., colleagues and friends) believe he or she should use the new system [37]. The concept of social influence is similar to "subjective norm" in the theory of planned behavior (TPB), which reveals that social influence has a strong effect on the individual's intention to perform certain behaviors [164]. Several studies have unveiled that social influence is a key factor in positive usage behavior [221], [223], [228], [227]. However, Chiu and Wang [218] found in their study that social influence does not have a significant influence on the intentions to use a technology system. In the current

research, it is assumed that when students have a positive influence from their colleges regarding using computational design tools, they will develop a positive usage behavior toward these tools. Thus the third hypothesis is formulated:

H1.3: A high level of social influence will positively affect students' usage behavior towards using computational design tools.

d. Facilitating Conditions

Facilitating Conditions refers to the extent to which a user believes that an organizational and technical infrastructure exists to support the use of the system [37]. Efficient adoption of a certain technology requires users to have access to the facilities and get the needed technical support from professionals [37], [207], [228]. A number of studies displayed that there is a significant correlation between facilitating conditions and user behavior toward a technology system [40], [220], [226], [227].

In contrast, Chiu and Wang [218] and Al-Gahtani & Hubona [225] found that facilitating conditions does not have a significant influence on user intention to adopt a technology system. In addition, a study by Thompson et al. [167] showed that there is a negative relationship between facilitating conditions and PC utilization. However, the researchers concluded that these results should be revised as they measured only one aspect of the facilitating conditions. They referred to earlier studies done by Amoroso in 1986, Jobber and Watts in 1986, and Lucasin in 1978 that showed a strong relationship between facilitating conditions and technology use. The current research assumes that the existence of design studios, computer labs, and technical infrastructure assist design students during their usage of computational design tools; therefore students would

develop positive usage behavior toward these tools. Thus the fourth hypothesis is formulated:

H1.4: A high perceived level of facilitating conditions will positively affect students' usage behavior towards using computational design tools.

e. Attitude toward using CDT

Attitude toward using technology is defined as the user's overall affective reaction to using a system [37]. While the UTAUT model considers user attitude toward a technology to be an indirect factor, TAM deems that attitude toward using a technology has a strong relationship with the actual use of the technology. C-TAM-TPB suggests that attitude influences behavioral intentions to use a system [165]. In addition, researchers suggested the importance of studying attitude as a main factor that causes effects on usage behavior [229], [230]. Several researchers found that a positive attitude toward using a system influences usage behavior positively [40], [205], [223], while Peng et al. [44] found that there is no significant relationship between attitude and behavioral intentions. In the current research, it is argued that students' positive or negative feelings about using computational design tools would affect their usage behavior.

H1.5: A positive attitude toward computational design tools will positively affect students' usage behavior towards using computational design tools.

f. Self-efficacy

Self-efficacy is defined as the judgment of an individual's ability to use a technology or information system to accomplish a particular job or task [231]. Self-efficacy concept

was first coined by Albert Bandura in 1977 [231]. Originally, self-efficacy was a main construct in the Social Cognitive Theory (SCT), which was also developed by Bandura in the 60s [168]. Although self-efficacy is a significant construct in SCT, the UTAUT model includes it as an indirect factor that influences behavioral intentions [37]. However, several studies found that self-efficacy affects user's behavior and behavioral intentions toward a technology system [218], [232], [233], [234]. In this thesis, it is argued that students' higher self-efficacy level in using computational design tools will influence their usage behavior positively.

H1.6: A high level of self-efficacy in using computational design tools will positively affect students' usage behavior towards using computational design tools.

g. Anxiety

Anxiety refers to the trigger of anxious or emotional reactions such as fear when performing a behavior [37], [235]. Within the context of information systems and computer science, Simonson et al [236] defined computer anxiety as an individual's fear when confronted with using computers. Anxiety has been under-researched extensively by information systems and psychology scholars [237]. For instance, several studies evaluated the factors that lead to anxiety while utilizing technology systems and computers [238], [239]. Other studies located anxiety as an independent variable that affects technology utilization [232], [235] and ease of use of [237]. In contrast, Chiu & Wang [218] revealed in their study a significant negative relationship between anxiety and the usage behavior of a certain technology. In the current research, it is assumed that student's anxiety levels while using computational design tools will have a significant effect on their usage behavior toward these tools.

H1.7: Lower levels of anxiety while using computational design tools will positively affect students' usage behavior towards using computational design tools.



CHAPTER IV

METHODOLOGY

4.1 Research Methodology

This chapter focuses on presenting the research methodology used in this research. The research methodology is a series of procedures used to design the research and gather and analyze data [240]. There are many types of research methods in the architecture discipline including historical, qualitative, correlational, experimental, quasi-experimental, simulation, logical, case studies, and combined strategies research [241]. However, since the current research is interdisciplinary research that utilizes theories from socio-psychology and information systems disciplines, it was important to look up research types in these domains. Within the socio-psychology domain, there are several research methods such as observational, correlational, and experimental research [242]. The research methods included in the information systems discipline are survey (quantitative approach), experimental design, design-science research, case study, bibliometric research, action research, historical research, ethnographic research, and constructivist grounded theory [56].

Choosing the research method should consort with the aim and the objectives of the research. This research aims to study the factors that influence design students' usage behavior and behavioral intention to use computational design tools by utilizing the Unified Theory of Acceptance and Use of Technology (UTAUT). Thus, this research is conducted in two stages. Firstly, a secondary research method (literature review) is adopted to collect existing related literature that shaped the background

information and the foundation for designing the primary research [8], [243]. Secondly, a quantitative approach is implemented through which the data is collected and analyzed [56]. The following section justifies these selections.

Table 3: Types of research methods

Architecture domain [241].	Socio-psychology domain [242].	Information systems domain [56].
• Historical research • Qualitative research • Correlational research • Experimental research • Simulation research • Logical research • Case studies research • Combined strategies research	• Observational research • Correlational research • Experimental research	• Survey (quantitative approach) • Experimental design • Design-science research • Case study • Bibliometric research • Action research • Historical research • Ethnographic research • Constructivist grounded theory

4.1.1 Secondary Research Method (Literature Review)

Secondary research is a widely employed research method that uses data that was researched by someone else [243]. There are several forms of secondary research, for example, literature review, case studies, content analysis, and statistical analysis [244]. The literature review helped the researcher to identify the gap in the literature, as far as the researcher's knowledge, and gave insights and information on whether this research should be conducted. Based on the goal of this research, a literature review was prepared as mentioned in chapter 2. The researcher dug into the body of precedent studies and research on the topic of computational design in architectural education and behavioral theories. The literature review provided the researcher with the needed knowledge to design and conduct the current research.

4.1.2 Quantitative Approach

A quantitative approach is the process of collecting and analyzing data statistically [245]. This approach can be used for different types of research such as correlational, descriptive, and experimental research. In correlational research, a quantitative approach is used to collect the data through a questionnaire survey, test the hypotheses, and draw statistical conclusions [246]. The strength of the quantitative approach is that it summarizes large amounts of data into graphs and charts. In addition, the quantitative approach can test research hypotheses statistically. It also provides a precise answer to a specific question. Based on this answer- taking into consideration other factors such as sampling methods and sample size- the statistical results can be translated to draw a general conclusion regarding the population in the studied domain [245].

The current research utilizes the quantitative approach to collect the data, test a set of hypotheses and analyze the research variables through statistical analysis techniques that will be elaborated in the following section. This study employs the questionnaire survey from the UTAUT model which was developed and evaluated based on quantitative collected and analyzed data [37].

4.2 Research Design

In academic research, research design plays a pivotal role in guiding the research procedures [245], [247]. Research design is a set of decisions regarding the purpose and type of the study, location, unit of analysis, methodology, data collection, and analysis [245].

4.2.1 The Purpose of the Research

Researchers conduct studies for many purposes. Studies can be exploratory, descriptive, or explanatory [248]. Each type serves different purposes. Exploratory research aims to develop an initial understanding of a phenomenon. The descriptive research goal is to give an accurate measurement and reporting of attributes of some population or phenomenon. Explanatory research is a type of research that provides reporting of the relationship of variables within a phenomenon [245].

The purpose of the current research is explanatory, as this research aims to test a set of hypotheses that explain the relationship between a group of variables and students' usage behavior and behavioral intentions.

4.2.2 The Type of the Research

Correlation research is a type of research that assesses statistically the relationship between two or more variables [242]. The researcher in this type of research puts no effort into controlling the variables [246]. The goal of this type of research is to find the correlation between two or more variables by searching for and testing hypotheses [242].

Correlational research has several general characteristics; one of them is that it focuses on naturally occurring relationships between the variables [241]. Researchers utilizing the correlational research method cannot manipulate the variables as what happens in the experimental research method when the researcher can assign some active changes and interventions on the independent variable and test its effect on the dependent

variable [246]. This distinction is important because the researcher in the correlational research method simply measures the variables and analyzes the relationships between them [241]. For instance, within the context of this research, the researcher obtained data on students' opinions regarding performance expectancy of computational design tools through a self-assessment questionnaire survey, without putting the students in an experimental setting and manipulating the environment to test their opinions.

The second characteristic is that correlational research uses statistics to clarify the relationship between the variables [241], but unlike the experimental research method, correlational research cannot draw conclusions regarding the causal relationship between the variables [242]. This means that the presence of a correlation between two variables does not necessarily imply that either one of the variables caused the other [246]. For instance, in the context of this research, it is hypothesized that effort expectancy will positively affect students' usage behavior of computational design tools; this does not mean that ease of use of the tools necessarily caused a positive usage behavior.

Depending upon the nature of this research which has a set of hypotheses, this research is correlational as it examines the relationship between the independent variables (performance expectance, effort expectance, social influence, facilitating condition, attitude towards CD tool, self-efficacy, and anxiety) and the mediating variable (usage behavior) and dependent variable (behavioral intentions).

4.2.3 The Research Settings, Location, and Time

Since this study is correlational research, as mentioned earlier, it was conducted in non-contrived settings. In non-contrived settings, the research is conducted in a natural

environment not in any lab setting [246]. In the current research, a questionnaire survey was distributed to fourth-year architectural design students via email.

This research was conducted in the Department of Architecture in the Faculty of Architecture and Design at Özyeğin University. Students involved in the architecture design program at this university undergo two stages of development during their studies. In the first stage, the initial year, they enroll in courses covering various topics among which are architectural design and drafting techniques courses. In the second stage, from the second to the fourth year, students engage in a series of workshops that introduce them to using computer-aided design tools alongside other architecture courses.

This study is cross-sectional research as it aims to collect data at one time [242]. It was conducted outside the studio settings as the questionnaire survey was sent via email to the participants to fill out. The needed time to fill up the survey was 25-30 minutes. This research was done in the spring of 2023.

4.2.4 The Unit of Analysis and Participants

The unit of analysis refers to the individual, groups, organizations, social interactions, or artifacts being studied by the researcher [245]. In this research, the unit of analysis is the individuals (fourth-year students) enrolled in the architecture design program. Thirty students volunteered to participate in the study, with a gender distribution of 72.41% female and 27.59% male.

4.3 Data Collection

Data collection is the process of gathering data about a particular topic. These methods include observations, surveys, focus groups, and experiments, depending on the goal of the research [245]. Based on the purpose of this research, which is evaluating the factors that affect design students' usage behavior and behavioral intention toward computational design tools, a quantitative method (questionnaire survey) was used to be the method for collecting the data. The questionnaire survey was adopted from the unified theory of acceptance and use model (UTAUT).

A questionnaire survey is an efficient tool to gather the needed data for research [246]. Survey research in general is non-experimental and preferred by researchers as a tool to get accurate estimates regarding the targeted population [246]. In some cases, survey research can be experimental as the researcher manipulates the independent variables to assess their effect on a dependent variable.

The current research, as mentioned in section 4.2.3, is non-experimental as the researcher distributed the survey via email to the participants and did not assign any interventions.

Before distributing the survey, the researcher informed the participants about the survey and if they were willing to participate or not. A consent form that includes a brief about the study was distributed to the participants to introduce them to the purpose of the study.

4.3.1 The Questionnaire Survey

The questionnaire survey included three sections; the first section, section (A), collected demographic information such as age, gender, experience duration, and skill level. While information such as age was gathered, it was excluded from the analysis because all students who participated in the survey belonged to the fourth year of the undergraduate architecture program and were aged between 21 and 24. The second section, section (B), was concerned with collecting data on the factors (independent variables) that affect students' usage behavior and behavioral intentions. The third section, section (C), contained items about usage behavior (mediating variable) and behavioral intention (independent variable).

The questionnaire items used in sections (B) and (C) are mostly adopted from the unified theory of acceptance and use (UTAUT) by Venkatesh et al. [37]. Additional Items were adopted from [40], [175], [176], [211], [249], [250] providing inherent validity to the questionnaire. The wording of the items was modified to fit the context of the research.

Section A of the survey consisted of 5 items that were formulated based on nominal and ordinal scales (Table 1). Section B comprised 42 items designed using ordinal scales. These items were measured using a five-point Likert scale ranging as follows: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree =4, and Strongly agree = 5 (Table 2). Section C included 10 items formulated using nominal and ordinal scales (Table 3). A detailed explanation of the measurements is available in Appendix A.

Table 4: Questionnaire survey sections

Sections	Items content	Number of items
A	Items on demographic information	5 items
B	Items on the determinants: ▪ Performance expectancy ▪ Effort expectancy ▪ Social influence ▪ Facilitating conditions ▪ Attitude ▪ Self-efficacy ▪ Anxiety	42 items five-point Likert scale: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree =4, and Strongly agree = 5
C	Items on: ▪ Usage behavior ▪ Behavioral intention	10 items five-point Likert scale: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree =4, and Strongly agree = 5

CHAPTER V

DATA ANALYSIS AND DISCUSSION

The preceding chapters will delve into the background, problem statement, aim, objectives, and hypotheses of this study, focusing on the exploration of design students' usage behavior and behavioral intentions towards computational design tools. The current chapter embarks on the critical task of analyzing the gathered data to discern patterns, relationships, and insights that contribute to a deeper understanding of the factors influencing students' utilization of computational design tools.

The aim is to identify the factors shaping usage behavior and behavioral intentions, explore students' comprehension of computational design technology, and assess how demographics influence their tool usage. The analysis is guided by the Unified Theory of Acceptance and Use of Technology (UTAUT), focusing on performance expectancy, effort expectancy, social influence, facilitating conditions, attitude, self-efficacy, and anxiety.

Self-assessment data, including usage patterns, experiences, and preferences, will be scrutinized. Research hypothesis, rooted in theoretical frameworks, will be rigorously tested through statistical analyses. The contributions of various factors to students' usage behavior and, in sequence, behavioral intentions will be evaluated.

This analysis aims to contribute insights to both academic discussions in architectural education and practical considerations for educators and technology developers. By unraveling the dynamics of students' engagement with computational design tools, the study seeks to inform future curriculum and technology development.

The subsequent sections will present findings, interpretations, and implications derived from the thorough examination of the data.

Firstly, descriptive statistics is used to understand students' opinions regarding the seven factors that are proposed in this study: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Attitude (AT), Self-Efficacy (SE), and Anxiety (A).

Secondly, the researcher will analyze the influence of the independent variables on the dependent variables by using Linear Regression Analysis. The decision of the output will be done regarding the output of (calculated t) comparing it with the value of (scheduled t), putting the confidence interval of 95%. In case (calculated t) is bigger than (scheduled t) with the level of significance less than (0.05), then the null hypothesis (H_0) will be rejected. Moreover, the null hypothesis (H_0) will be rejected if the level of significance less than 0.05 even though the (calculated t) is less than (scheduled t).

5.1 The Demographics Factors

This section undertakes a comprehensive demographic analysis to shed light on the varied characteristics of the design student participants in our study. Demographic factors play a pivotal role in shaping individuals' preferences, skills, and experiences,

particularly in the context of utilizing Computational Design (CD) tools in architectural design education. The demographic questions encompass a spectrum ranging from basic personal details such as gender and age to inquiries delving into the students' preferences, self-assessed skills, and the duration of their engagement with CD tools. Additionally, insights into the students' proficiency across specific CD tools, the sources of their experience, and their preferred methods of learning contribute to a holistic understanding of the diverse participant profiles. This analysis sets the stage for subsequent in-depth examinations, allowing us to discern patterns and correlations within the broader demographic landscape of design students participating in this study.

The study's gender distribution has a notable majority of female participants, comprising 72.41%, compared to 27.59% of male participants (Figure 20). This gender imbalance may influence our findings, as gender dynamics can play a role in shaping attitudes and behaviors, particularly in technology adoption [37]. Acknowledging this distribution, subsequent analyses will consider potential gender-related influences on participants' preferences, usage behaviors, and behavioral intentions.

The age distribution among the participants indicates a varied representation, with the majority falling within the younger age brackets. Specifically, 22-year-olds constitute the largest group at 34.26%, followed by 21-year-olds at 25.43% and 23-year-olds at 27.85%. This age diversity is crucial to consider in our analysis, as different age groups may exhibit distinct preferences and experiences with computational design tools, potentially influencing usage behaviors (Figure 21).

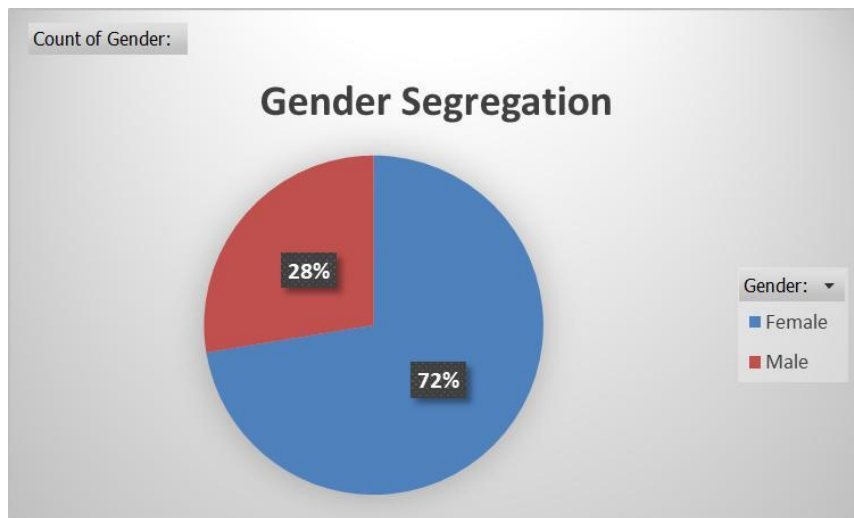


Figure 20: Gender Segregation of participants

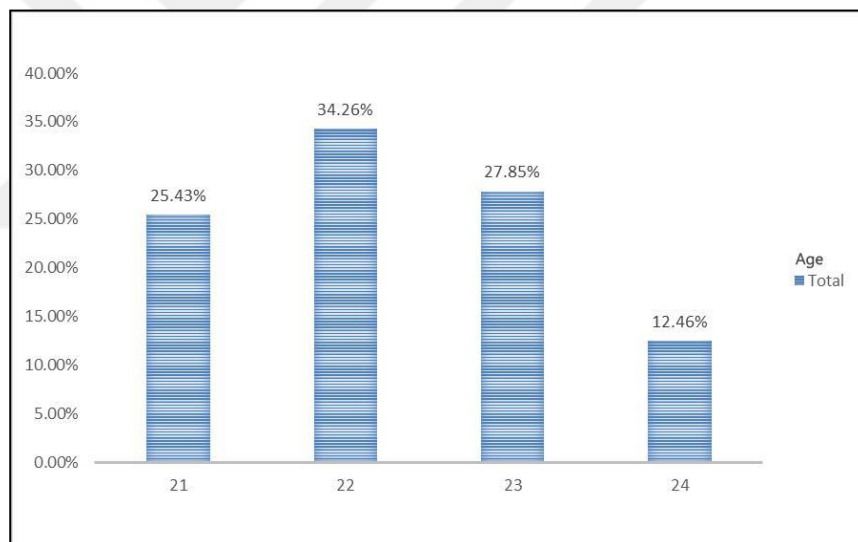


Figure 21: Age Segregation of participants

The majority of design students' experience in using Computational Design (CD) tools is two to four years, constituting 72.4%. A significant portion, 24.1%, have experience of one to two years. A smaller percentage have experience of four to six years (3.4%). This distribution suggests a recent and predominant adoption of CD tools

among the participants, impacting their familiarity and potential expertise with these tools (Figure 22).

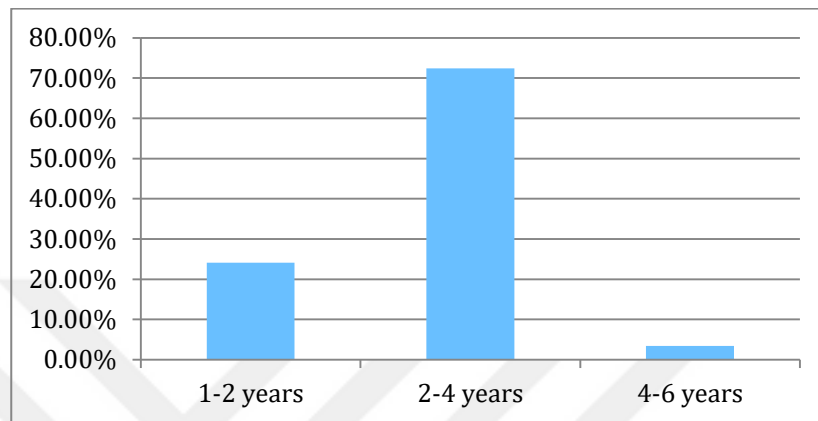


Figure 22: Experience Segregation of participants

Regarding the preference for using Computational Design (CD) Tools in curriculum design projects, a significant 90% of design students expressed a preference, with 34.6% rating their preference as "Very good." In contrast, 10% indicated a preference for not using CD Tools (Figure 23).

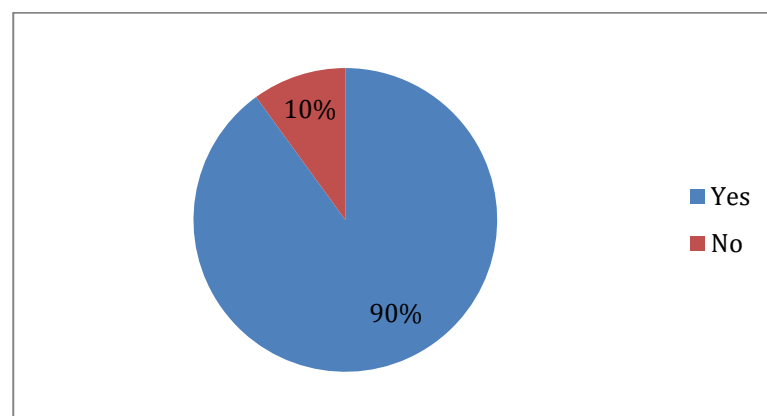


Figure 23: Preferences of using CD tools

In terms of self-rated skills, a noteworthy 55.17% of participants consider their skills in using CD Tools as "Good," with 31.03% rating their skills as "Very good." On the other hand, 10.3% and 3.45% rated their skills as "Fair" and "Excellent" respectively. These insights into preferences and self-rated skills provide a foundation for understanding the students' comfort and proficiency levels with CD Tools in the context of curriculum design projects (Figure 24).



Figure 24: Skills in using CD tools

The skills rating across different Computational Design (CD) Tools provides valuable insights into the proficiency levels of design students (Table 5):

AutoCAD: The majority rates their skills as "Very good" (55%) or "Excellent" (34%).

Microstation: Primarily rated as "Poor" (93%), indicating a lower level of proficiency.

Rhinoceros 3D: Varied ratings, with a significant proportion rating their skills as "Good" (24%) and "Very good" (21%).

Grasshopper: Predominantly rated as "Poor" (59%), (24%) as "Fair", and (14%) as good, suggesting challenges in proficiency.

Ecotect: High ratings in the "Poor" category (97%), indicating a significant need for improvement.

Revit: Varied ratings, with "Very good" (17%) and "Good" (17%) being notable.

ArchiCad: A diverse range of ratings, with "Very good" (17%) and "Good" (10%) standing out.

3DMax, Maya, Sketch Up, Dynamo, Galapagos, EnergyPlus: Varied ratings across these tools emphasize poor skill levels.

This comprehensive overview allows us to identify areas where students excel and areas that may require additional attention or support in their skills development with specific CD Tools.

Table 5: Participants skills in different CD Tools

skill	A C	M S	RC	GH	ET	RV	AD	3D	M Y	S U	D N	GP	EP
Excellent	34%	0%	3%	3%	0%	0%	3%	0%	0%	21%	0%	0%	0%
Very good	55%	3%	21%	0%	0%	17%	0%	3%	0%	48%	0%	0%	0%
Good	7%	0%	24%	14%	0%	17%	10%	17%	0%	17%	0%	0%	0%
Fair	3%	3%	28%	24%	3%	45%	14%	28%	7%	7%	7%	0%	0%
Poor	0%	93%	24%	59%	97%	21%	72%	52%	93%	7%	93%	100%	100%

Q4: How do you rate your skills in CD Tools?

AC=AutoCAD, MS=Microstation, RC=Rhinoceros 3D, GH=Grasshopper, ET=Ecotect, RV=Revit. AD=ArchiCad, 3D=3DMax, MY=Maya, SU=Sketch Up. DN=Dynamo, GP=Galapagos. EP=EnergyPlus

Design students have diverse preferences when it comes to the most useful ways of learning Computational Design (CD) Tools. The analysis of their rankings indicates the following distribution (Figure 25):

Personal Effort (24.14%): Emerges as the most preferred method, underscoring the significance of self-directed learning in acquiring proficiency with CD Tools.

University Lab Course (24.14%): Equally favored, highlighting the importance of structured academic courses in enhancing skills.

Online Tutorials (17.24%): A substantial proportion values learning through tutorials and books, emphasizing the role of written resources.

Design Studio (13.79%): Indicates a preference for external courses, potentially reflecting a desire for specialized, focused training.

Private Course (10.34%): Suggests the value placed on hands-on, project-based learning within the academic setting.

Tutorials Books (3.45%): While less prominent, online classes remain a notable choice for some students.

Architectural Practice, Internship (3.45% each): Indicate a lower preference, potentially due to the practical focus of these options.

This analysis provides valuable insights into the varied learning preferences among design students, allowing for tailored approaches in educational settings to enhance proficiency with CD Tools.

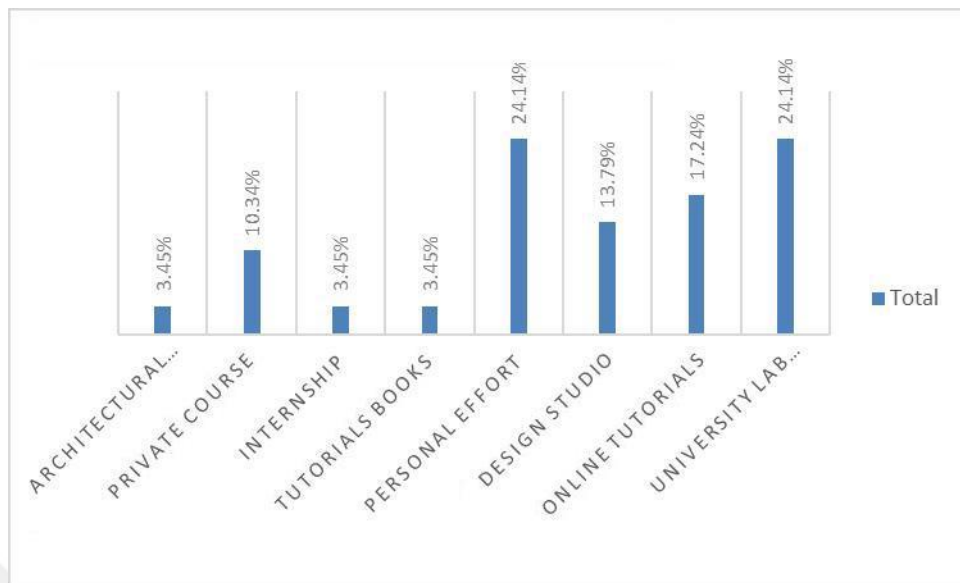


Figure 25: participants 1st preference in learning CD tools

5.2 Reliability Test

The reliability test is taking place to ensure that the questionnaire has the reliability and validity of testing the hypothesis, which means even if the survey is distributed again the result will stay the same. The researcher is conducting the reliability test even though the majority of the survey was taken from Venkatesh et al. [37].

Table 6: Reliability statistics

Cronbach's Alpha	N of Items
.799	9

Table shows that after conducting the Cronbach's Alpha statistic test, the reliability is 79.9%, which is more than 60% and we can say that the survey is reliable for the search that is made for [251] (Table 6).

5.3 Descriptive Statistics for UTAUT determinants and Discussions

In this section, descriptive statistics of UTAUT determinants/factors will be presented. The Questionnaire employed a 5-point Likert scale for its items ranging from Strongly disagree to Strongly agree. Items with a score above 3.5 indicate a high level of agreement/ positive opinion toward the UTAUT factor, while scores between 2.7 and 3.4 indicate a moderate level of agreement/ neutral opinion toward the UTAUT factor. Scores below 2.6 reflect a low level of agreement/ negative opinion toward the UTAUT factor.

a. Performance expectancy:

The descriptive analysis reveals positive perceptions among participants regarding the usefulness of Computational Design (CD) Tools in architectural projects. Notably, for the item (PE1), respondents strongly agree (Mean = 4.61) that CD Tools would be beneficial in their design projects, showing limited variability in responses (Std Dev = 0.82). While for items (PE2) and (PE3), participants generally agree that CD Tools contribute to quicker task accomplishment and increased productivity (Means = 4.35 and 4.17, respectively), opinions exhibit more variability (Std Dev = 1.07 and 0.99). For item (PE4), the notion that CD Tools enhance creative design possibilities also garners agreement (Mean = 4.03), with moderate variability in responses (Std Dev = 1.00). However, for the item (PE5), perceptions about the time efficiency of CD Tools (Mean = 3.41) exhibit more diverse opinions (Std Dev = 1.38). For items (PE6) and (PE7), participants agree that CD Tools provide greater control over designs (Mean = 4.17), and using these tools has improved their architectural design skills (Mean = 4.03), with high agreement and limited variability in responses for both items (Std Dev = 0.99 and

0.96, respectively). The overall mean of the factor Performance Expectancy is 4.11, which indicates that students perceive that using computational design tools is useful and helps them achieve their goal in design (Table 7).

Table 7: Descriptive statistics for performance expectancy

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(PE1) I would find using CD Tools useful in my design projects	3%	0%	3%	24%	69%	100%	4.61	0.81676
(PE2) Using CD Tools enable me to accomplish my design task more quickly	7%	0%	10%	31%	52%	100%	4.35	1.07210
(PE3) Using CD Tools increase my productivity	4%	4%	0%	42%	50%	100%	4.17	0.98502
(PE4) By using CD Tools, I will increase my chances of coming up with better/ more creative designs	4%	4%	0%	46%	46%	100%	4.03	0.99941
(PE5) The use of CD Tools consumes less time compared to conventional design tools	17%	17%	0%	33%	33%	100%	3.41	1.37759
(PE6) Using CD Tools give me greater control over my design	4%	4%	0%	42%	50%	100%	4.17	0.98502
(PE7) Using CD Tools in curriculum design projects have improved my architectural design skills compared with traditional tools	4%	4%	0%	52%	40%	100%	4.03	0.96428

Overall mean							4.11	
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According to the results above, it is clear that most students perceive using CD tools as useful to their design and help them accomplish their tasks quickly. This might be because CD tools save students time when it comes to some repetitive tasks that computer software can do with few clicks. Most of the students also agreed that CD tools give them more control over their designs and help them produce more creative designs; this can be due to the functions that are provided by these tools which allow students to manipulate their designs until they get the desired result. However, fewer students agreed that CD tool save their time compared to conventional tools. This result might seem to contradict the result of item (PE2), however, it is not. The explanation is that they believe that these tools quicker their task accomplishments but they are not professional enough to use the tools to the level that they use less time compared to the conventional tools.

b. Effort expectancy:

The descriptive analysis for items related to Effort Expectancy (EE1) indicates that participants generally find CD Tools clear and understandable (Mean = 3.76), expressing a high level of agreement with limited variability (Std Dev = 0.86). Respondents to the item (EE2) also agree that it is easy for them to become skillful and professional at using CD Tools (Mean = 3.79), with a high level of agreement and a relatively small standard deviation (Std Dev = 0.92). Furthermore, for the item (EE3), participants find CD Tools easy to use in their curriculum design projects (Mean =

3.76), showing a high level of agreement and low variability (Std Dev = 0.77). For item (EE4), the perception of quick learning (Mean = 3.55) exhibits a high agreement with a relatively small standard deviation (Std Dev = 0.81). Respondents to items (EE5) and (EE6) strongly agree that CD Tools are flexible to use (Mean = 3.79) and find it easy to remember how to perform tasks using these tools (Mean = 3.76), with both items demonstrating a high level of agreement and limited variability (Std Dev = 0.76 and 0.86, respectively). The overall mean of the factor Effort Expectancy is 3.76 which represents positive opinions regarding the effort expectancy factor (ease of use) (Table 8).

Table 8: Descriptive statistics for effort expectancy

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(EE1) CD Tools are clear and understandable	4%	8%	0%	77%	12%	100%	3.76	0.85723
(EE2) It is easy for me to become skillful and professional at using CD tools	5%	5%	0%	64%	27%	100%	3.79	0.92398
(EE3) I find CD Tools easy to use in my curriculum design projects	5%	0%	0%	82%	14%	100%	3.76	0.77260
(EE4) I learned how to use CD Tools quickly	5%	5%	0%	79%	11%	100%	3.55	0.81309
(EE5) I would find CD Tools to be flexible to use	4%	0%	0%	83%	13%	100%	3.79	0.76019
(EE6) It is easy for me to remember how to perform tasks using CD Tools.	4%	4%	0%	74%	17%	100%	3.76	0.85723
Overall mean							3.76	

Based on the previous results, it is shown that generally, the students perceive that becoming skillful in the CD tool is easy. Comparing this result with Facilitating Conditions (FC4) and (FC5) items, it can be interpreted that students believe that it is easy for them to become skillful if they have enough time during the semester. In addition, this result confirms the result from Self-efficacy (SE1) and (SE2) which shows that the students have high self-efficacy in using CD tool. Students also consider CD tools flexible and understandable because they mainly use low-moderate complexity CD tools. Only a few students have experience in using high-complexity CD tools as shown in Figure 3.

c. Social Influence:

The descriptive analysis for items related to Social Influence reveals that participants express varied perceptions about the factors influencing their use of CD Tools. For item (SI1), participants, on average, moderate level of agreement with the students that they use CD Tools because they are influenced by other students (Mean = 3.24), with a notable standard deviation indicating diverse opinions (Std Dev = 0.97). For (SI2), the studio master in the design course is perceived as helpful in encouraging the use of CD Tools (Mean = 3.45), with a high level of agreement and a relatively small standard deviation (Std Dev = 0.93). Moreover, for item (SI3), the social environment of the studio is seen as supportive of CD Tools' use (Mean = 3.55), demonstrating high agreement with moderate variability (Std Dev = 1.00). Conversely, fewer respondents to item (SI4), feel pressured and forced to use CD Tools due to peer influence (Mean = 2.86), with a higher standard deviation suggesting more diverse opinions (Std Dev =

1.22). Additionally, for item (SI5), students who use CD Tools are perceived to have more prestige in the studio (Mean = 3.76), with a high level of agreement and a notable standard deviation indicating varying perspectives (Std Dev = 1.10). The overall respondents mean is 3.37, which indicates a neutral opinion regarding the social influence factor (Table 9).

Table 9: Descriptive statistics for social influence

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(SI1) I use CD Tools because I got influenced from the students around me	5%	30%	0%	55%	10%	100%	3.24	0.97043
(SI2) The studio master in design course has been helpful in encouraging the use of CD Tools	5%	18%	0%	68%	9%	100%	3.45	0.93167
(SI3) The social environment of the studio has supported the use of CD Tools	9%	9%	0%	70%	13%	100%	3.55	1.00297
(SI4) I feel pressured and forced to use CD Tools in design projects because everyone use them	26%	22%	0%	48%	4%	100%	2.86	1.22402
(SI5) Students in studio who use CD Tools have more prestige than those who do not	4%	16%	0%	48%	32%	100%	3.76	1.10345
Overall Mean							3.37	

According to Social Influence items results, most of the students think that using CD tools is prestigious. This result might be because the students who are professional in utilizing CD tools develop more creative designs compared to those who don't, thus other students perceive them with a very positive view. In addition, they agree that the

studio's social environment and the studio master encourage utilizing CD tools. Fewer students think that they are forced to use computational design tools because everyone in the studio uses them. It can be interpreted that the studio environment is supportive and does not put pressure on the student regarding utilizing CD tools.

d. Facilitating Conditions:

The descriptive analysis for items related to Perceived Facilitating Conditions indicates participants' perceptions regarding the availability of necessary resources for using CD Tools. On average, respondents for item (FC1) agree that they have the necessary resources to use CD Tools (Mean = 4.00), suggesting a high level of agreement and limited variability (Std Dev = 0.79). Participants also express agreement wastem (FC2) that they have learned and trained with the necessary knowledge to use CD Tools (Mean = 3.76), with a high level of agreement and a moderate standard deviation (Std Dev = 0.90). Regarding guidance availability in item (FC3), respondents somehow agree that guidance from a specific person or group is available to assist with CD Tools difficulties (Mean = 3.28), with a higher standard deviation indicating more diverse opinions (Std Dev = 1.01). For items (FC4) and (FC5), final-year students, opinions vary regarding the adequacy of the previous semester periods for learning to use CD Tools professionally (Mean = 2.93, Std Dev = 0.94) and gaining an intermediate level of proficiency (Mean = 3.66, Std Dev = 0.84). The overall mean of Facilitating Conditions is 3.53 (Table 10).

Table 10: Descriptive statistics for facilitating conditions

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(FC1) I have the necessary resources to use CD Tools	4%	0%	0%	73%	23%	100%	4.00	0.78784
(FC2) I have learned and trained with the necessary knowledge to use CD Tools	4%	8%	0%	72%	16%	100%	3.76	0.89655
(FC3) Guidance from a specific person or group was available to me to assist me with CD Tools difficulties	5%	30%	0%	50%	15%	100%	3.28	1.01358
(FC4) As a final-year student, I think that the period of previous semesters was enough to learn using CD Tools professionally	12%	41%	0%	41%	6%	100%	2.93	0.94435
(FC5) As a final-year student, I think that the period of previous semesters was enough to gain an intermediate level of using CD tools	5%	5%	0%	76%	14%	100%	3.66	0.84183
Overall Mean							3.53	

As it is shown in the results most of the students think that necessary resources and training are available during their study. It can be interpreted from this that the studio's technical environment is strong. However, moderate level of agreement among the students on the availability of assistance when confronting difficulties while using CD tools. This result might be due to the limited time during the semester. This result is confirmed by students' opinions that semester time is enough only to gain an intermediate level in utilizing CD tools. It can be concluded that there is a need to provide the students with more time to gain enough knowledge. This result is also

confirmed with the item (EE2) from the Effort Expectancy factor which indicated that there is moderated agreement on the ease of becoming skillful in using CD tools as shown earlier.

e. Attitude toward CD tools:

The descriptive analysis for items related to Attitude demonstrates participants' positive perceptions about the enjoyment and satisfaction associated with using CD Tools in curriculum design projects. On average, respondents to item (AT1), express agreement that CD Tools make designing more interesting (Mean = 3.86), with a high level of agreement and a moderate standard deviation (Std Dev = 0.94). Additionally, for the item (AT2), participants strongly agree that designing with CD Tools is fun and enjoyable (Mean = 4.03), with a high level of agreement and a relatively small standard deviation (Std Dev = 0.85). The item (AT3): "I like using CD Tools in my curriculum design projects" garners high agreement (Mean = 4.34) and limited variability (Std Dev = 0.84). For (AT4), participants agree that using CD Tools makes them feel more confident with their designs (Mean = 4.00), with a high level of agreement and a notable standard deviation indicating diverse opinions (Std Dev = 0.91). Moreover, for the item (AT5), CD Tools are perceived to give participants the courage and motivation to accomplish design projects (Mean = 4.07), with a high level of agreement and a moderate standard deviation (Std Dev = 0.87). For the last item (AT6), participants expressed satisfaction with using CD Tools in their design projects (Mean = 4.00), with a notable standard deviation suggesting diverse opinions (Std Dev = 1.05). The overall mean of student attitude is 4.05, indicating a positive view toward the CD tool (Table 11).

Table 11: Descriptive statistics for attitude

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(AT1) CD Tools make designing more interesting	4%	4%	0%	61%	30%	100%	3.86	0.93676
(AT2) Designing with CD Tools are fun and enjoyable	4%	0%	0%	64%	32%	100%	4.03	0.85026
(AT3) I like using CD Tools in my curriculum design projects	4%	0%	0%	46%	50%	100%	4.34	0.84183
(AT4) When using CD Tools I feel more confident with my design	4%	0%	0%	57%	39%	100%	4.00	0.90972
(AT5) CD Tools give me the courage and motivation to accomplish the design project	4%	0%	0%	60%	36%	100%	4.07	0.86825
(AT6) I am satisfied with using CDT in my design project	8%	0%	0%	52%	40%	100%	4.00	1.05045
Overall Mean							4.05	

According to the result, most of the students have positive opinions toward CD tools. A high level of agreement was that they liked using the tools. They also agreed that they feel encouraged and motivated to use them. In addition, the majority of the students think that CD tools are fun and interesting. It can be interpreted that CD tools can provide the student with a variety of options and solutions for their design. The students can get creative results if they know how to use CD tools professionally. This result confirms the result from the item (PE4) in the Performance Expectancy factor

which indicated that students believe that CD tools help them produce more creative designs.

f. Self-Efficacy:

The descriptive analysis for items related to Self-Efficacy reveals participants' confidence in their abilities to use CD Tools effectively in curriculum design projects. For item (SE1), on average, respondents strongly agree that they can recover from mistakes quickly and easily while using CD Tools (Mean = 4.00), with a high level of agreement and a low standard deviation (Std Dev = 0.59). For item (SE2), participants express agreement that they can solve most problems without someone around to guide them (Mean = 3.86), with a high level of agreement and a moderate standard deviation (Std Dev = 0.86). Additionally, respondents to the item (SE3) agree that they can find solutions to problems while using CD Tools without external assistance or support videos (Mean = 3.40), with a moderate level of agreement and a notable standard deviation indicating diverse opinions (Std Dev = 0.93). For item (SE4), participants strongly agree that they believe they have enough knowledge to use CD Tools in their curriculum design projects (Mean = 4.10), with a high level of agreement and a low standard deviation (Std Dev = 0.71). Moreover, for the item (SE5), participants agree that they can use CD Tools in their design projects with ease and proficiency (Mean = 3.83), with a high level of agreement and a relatively low standard deviation (Std Dev = 0.79). Respondents to the item (SE6) express agreement that they know how to utilize most CD Tools' functions and plug-ins (Mean = 3.52), with a high level of agreement and a notable standard deviation suggesting diverse opinions (Std Dev = 0.97). For item

(SE7), participants agree that they can complete tasks using CD Tools without asking for extra time (Mean = 3.52), with a high level of agreement and a moderate standard deviation (Std Dev = 0.90). Additionally, for the item (SE8), participants agree that when confronted with a problem, they can usually find several solutions while using CD Tools (Mean = 3.79), with a high level of agreement and a notable standard deviation indicating diverse opinions (Std Dev = 0.92). For item (SE9), participants strongly agree that they are confident they could deal efficiently with unexpected events while using CD Tools (Mean = 3.69), with a high level of agreement and a moderate standard deviation (Std Dev = 0.99). Lastly, for the item (SE10), participants agree that when designing with CD Tools, they can easily achieve the desired design they want (Mean = 3.86), with a high level of agreement and a relatively low standard deviation (Std Dev = 0.73). The overall mean value for students' self-efficacy in using the CD tool is 3.76 (Table 12).

Table 12: Descriptive statistics for self-efficacy

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
(SE1) I can recover from mistakes quickly and easily while using CD Tools	0%	0%	0%	79%	21%	100%	4.00	0.58722
(SE2) I can solve most problems without someone around to tell me	4%	4%	0%	72%	20%	100%	3.86	0.86000

what to do as I go.								
(SE3) Whatever comes my way while using CD Tools, I can find the solution without calling for assistance or access to support videos	0%	28%	0%	50%	22%	100%	3.40	0.929 12
(SE4) I believe I have enough knowledge on how to use CD Tools in my curricular design projects.	0%	4%	0%	65%	31%	100%	4.10	0.711 72
(SE5) I can use CD Tools in my design projects with ease and proficiency	4%	0%	0%	78%	17%	100%	3.83	0.790 85
(SE6) I know how to get the benefit of most CD Tools' functions and plug-ins.	5%	15%	0%	60%	20%	100%	3.52	0.969 20
(SE7) I can complete a task using CD Tools without asking for extra time.	5%	11%	0%	68%	16%	100%	3.52	0.895 22

(SE8) When I am confronted with a problem, I can usually find several solutions.	5%	0%	0%	58%	37%	100%	3.79	0.92398
(SE9) I am confident that I could deal efficiently with unexpected events while using CD Tools.	4%	13%	0%	63%	21%	100%	3.69	0.98623
(SE10) When I design with CD Tools I can easily achieve the desired design that I want.	0%	5%	0%	73%	23%	100%	3.86	0.72986
Overall Mean							3.76	

Based on the results, most of the students think that they have enough knowledge to use CD tools. In addition, most of the students believe that they can recover from their mistakes quickly and solve problems while using CD tools without asking for help or extra time. Similar numbers of students believe that they get the benefit of CD tools functions and plug-ins. The overall mean is 3.76 indicating that the students have a high level of self-efficacy in using CD tools. The interpretation is that most of the students are using low-moderate complexity CD tools as these tools are easy to use, while few students use high-complexity CD tools, as shown in Figure 3.

g. Anxiety:

For items related to Anxiety, the descriptive analysis indicates the extent to which final-year students experience anxiety and stress while using CD Tools in their design projects. For item (A1), on average, respondents agree that, as final-year students, they still feel anxious about using CD Tools (Mean = 2.69), with a moderate level of agreement and a notable standard deviation suggesting diverse opinions (Std Dev = 0.95). For item (A2), participants also agree that they still feel scared of making mistakes while using CD Tools (Mean = 2.76), with a moderate level of agreement and a relatively high standard deviation (Std Dev = 1.07). Additionally, for item (A3), participants express agreement that they feel stressed while using CD Tools (Mean = 3.10), with a moderate level of agreement and a high standard deviation (Std Dev = 1.16). Furthermore, for item (A4), participants agree that they can't control their anxiety when facing an issue during the use of CD Tools in their design projects (Mean = 3.10), with a moderate level of agreement and a notable standard deviation indicating diverse opinions (Std Dev = 1.12). These findings suggest that while some students experience anxiety and stress when using CD Tools, opinions on these factors vary among the respondents. The overall score of the Anxiety factor is 0.17 (Table 13).

Table 13: Descriptive statistics for anxiety

Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Total	Mean	Std Deviation
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(A1) As a final-year student I still feel anxious about using CD Tools.	6%	24%	0%	53%	18%	100%	2.69	0.95062
(A2) As a final-year student I still feel scared of making mistakes while using CD Tools.	9%	26%	0%	57%	9%	100%	2.76	1.07174
(A3) As a final-year student I still feel scared of making mistakes while using CD Tools.	9%	26%	0%	57%	9%	100%	2.76	1.07174
(A4) As a final-year student I feel stressed while using CD Tools.	8%	50%	0%	29%	13%	100%	3.10	1.15504
(A5) I can't control my anxiety when I face an issue during the use of CD Tools in my design project	21%	32%	0%	37%	11%	100%	3.10	1.12479
Overall Mean							0.17	

Based on the results about students' anxiety while using CD tools, it is shown that moderate level of agreement among the students that CD tools cause stress to them. Also, a moderate level of agreement indicated that anxious feelings cannot be controlled while using CD tools. Fewer students feel scared of making mistakes. These findings are confirmed by previous results from the item (SE1) in the Self-Efficacy factor as

most of the students agreed that they can recover from their mistakes quickly. The overall score of anxiety shows that a very small number of students experience anxiety while using the CD tool. The explanation might be, in addition to that they have high self-efficacy, is the available facilitating conditions. The items (FC1) to (FC5) in the Facilitating Conditions factor showed that students believe that there is strong technical support in the studio.

5.4 Hypothesis Testing, Results, and Discussions

The exploration of factors influencing students' usage behavior (UB) towards Computational Design (CD) tools extends into the realm of hypothesis testing, aimed at uncovering the intricate relationships within this context. The formulated hypotheses delve into various dimensions, ranging from the impact of performance and effort expectancy to the influence of social factors, facilitating conditions, attitude, self-efficacy, and anxiety. As hypothesis testing is undertaken, the aim is to dissect and discern the nuanced interplay of these elements, contributing to a more profound understanding of the dynamics that drive students' engagement with CD tools in the field of architectural education.

Regression Analysis, a statistical approach, will be used to test the relationship between independent variables and dependent variables [252].

In this study, two sets of regression analyses will be employed. The first will test eight hypotheses including (PE), (EE), (SI), (FC), (AT), (SE), and (A), and Usage Behavior (UB) as dependent variable. The second test will examine the relationship

between Usage (UB) Behavior as an independent variable and Behavioral Intentions (BI) as the dependent variable.

Main hypothesis:

The main hypothesis that this thesis studies is H1: Positive usage behavior towards CD tools will have a significant positive influence on students' behavioral intention to use the tools in the architecture practice after their graduation. Seven determinants affect usage behavior which in sequence will affect the behavioral intentions.

To test the main hypothesis (H1), the influence of the seven determinants (H1.1 - H1.7) on usage behavior will be first evaluated. Then H1 will be tested (Figure 26).

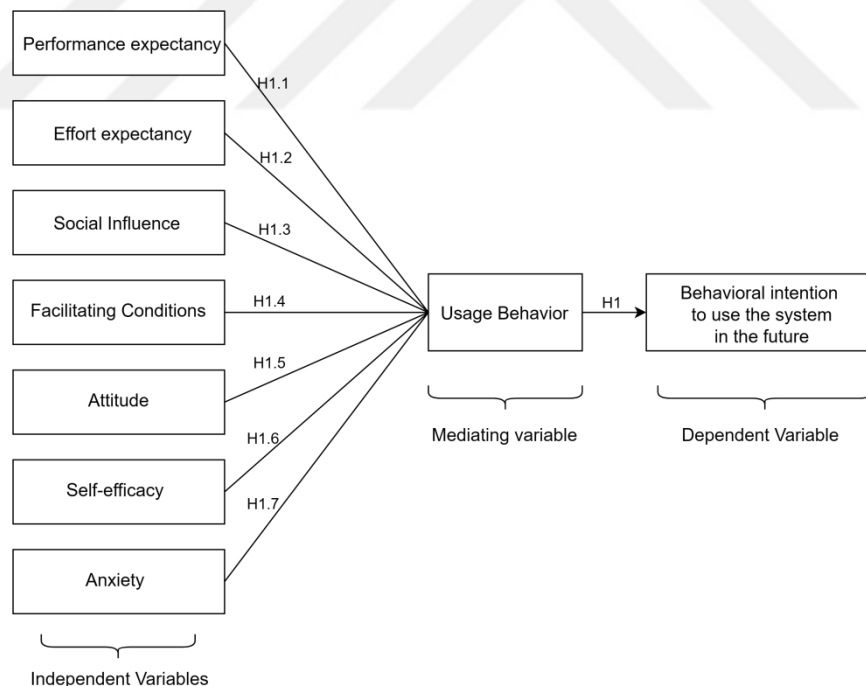


Figure 26: Research model

Performance Expectancy - Usage Behavior relationship (H1.1):

Testing H1.1: Performance expectancy will positively affect students' usage behavior towards using computational design tools.

This study delves into the relationship between Performance Expectancy and students' usage behavior with Computational Design (CD) tools. H1.1 proposes a positive influence of Performance Expectancy on usage behavior. To rigorously assess this, Regression analysis is employed, with Performance Expectancy as the independent variable and students' usage behavior as the dependent variable (Table 14).

Table 14: Results of testing H1.1.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.025 ^b	4.083	1.166	.219 ^a	0.048	1.359	Rejected Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics ($P=0.025$) is less than the level of significance (0.05), based on this the null hypothesis is rejected. Thus there is a significant relationship between Performance Expectancy and students' usage behavior with CD tools. Moreover, from the same table, it can be seen that the correlation coefficient (R) between performance expectancy and students' usage behavior is weak at (0.219). This is based on Goodwin & Leech (2006) which says the correlation coefficient determines the strength of the correlation between the variables, and they offer three guidelines as a scale for this strength, ($0 < |r| < 0.3$) weak correlation, ($0.3 < |r| < 0.7$) moderate correlation, and ($|r| > 0.7$) strong correlation. Therefore, it can be concluded that a positive role in students' usage behavior is played by performance expectancy, and this role is weak.

Effort Expectancy - Usage Behavior relationship (H1.2):

Testing H1.2: Effort expectancy will positively affect students' usage behavior towards using computational design tools.

H1.2 posits that Effort Expectancy plays a positive role in shaping students' usage behavior toward CD tools. To rigorously scrutinize this relationship, regression analysis is employed, with Effort Expectancy as the independent variable and students' usage behavior as the dependent variable (Table 15).

Table 15: Results of testing Null Hypothesis H1.2.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.563^b	4.121	11.4.585	.112 ^a	0.013	.343	Accept Null Hypothesis

The table shows that calculated (t) is smaller than scheduled (t), and the probability of (F) statistics ($P = 0.563$) is larger than the level of significance (0.05), regarding that the null hypothesis is accepted. Thus, it can be said that Effort Expectancy plays no role in students' usage behavior toward CD tools.

Social Influence - Usage Behavior relationship (H1.3):

Testing H1.3: A high level of social influence will positively affect students' usage behavior towards using computational design tools.

H1.3 emerges, proposing that a high level of social influence positively shapes students' usage behavior. To rigorously assess this relationship, our approach employs

regression analysis, setting social influence as the independent variable and students' usage behavior as the dependent variable (Table 16).

Table 16: Results of testing Null Hypothesis H1.3.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.046 ^b	4.91	6.82	.447 ^a	0.199	.541	Rejected Null Hypothesis

The table shows that calculated (t) is smaller than scheduled (t), and the probability of (F) statistics (P= .046) is less than the level of significance (0.05), regarding that the null hypothesis is rejected even though the (calculated t) is less than (scheduled t). Thus there is a relationship between Social influence and students' usage behavior toward CD tools. Moreover, the same table shows that the correlation coefficient (R) between Social influence and students' usage behavior is moderate at (0.447). Therefore, Social influence has a moderate positive role in students' usage behavior toward CD tools.

Facilitating Conditions - Usage Behavior relationship (H1.4):

Testing H1.4: A high perceived level of facilitating conditions will positively affect students' usage behavior towards using computational design tools.

H1.4 posits that a high perceived level of facilitating conditions positively influences students' usage behavior. This relationship is tested by employing regression

analysis, with perceived facilitating conditions as the independent variable and students' usage behavior as the dependent variable (Table 17).

Table 17: Results of testing Null Hypothesis H1.4.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.000 ^b	3.951	.617	.497 ^a	0.247	1.381	Rejected Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics ($P < 0.001$) is less than the level of significance (0.05), regarding that, the null hypothesis is rejected. Based on this there is a relationship between the facilitation conditions and students' usage behavior. Moreover, from the same table, it can be noticed that the correlation coefficient (R) between facilitating conditions and students' usage behavior is moderate at (0.497). Therefore, the facilitation conditions have a moderate positive role in students' usage behavior.

Attitude - Usage Behavior relationship (H1.5):

Testing H1.5: Positive attitude toward computational design tools will positively affect students' usage behavior towards using computational design tools.

H1.5 emerges as a key focal point in our exploration of factors shaping architecture design students' engagement with Computational Design (CD) tools. This relationship asserts that a positive attitude toward CD tools positively influences students' usage behavior. To rigorously test this proposition, regression analysis is

applied, designating positive attitude as the independent variable and students' usage behavior as the dependent variable (Table 18).

Table 18: Results of testing Null Hypothesis H1.5.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.471 ^b	4.177	.731	.139 ^a	0.019	.534	Accept Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics ($P = 0.471$) is larger than the level of significance (0.05), the null hypothesis is accepted even though the (calculated t) is bigger than (scheduled t). Based on this, a positive attitude toward CD tools has no role in students' usage behavior with CD tools.

Self-Efficacy - Usage Behavior relationship (H1.6):

Testing H1.6: A high level of self-efficacy in using computational design tools will positively affect students' usage behavior towards using computational design tools.

H6 proposes that a high level of self-efficacy in using CD tools positively shapes students' usage behavior. To rigorously test this proposition, our analytical journey involves regression analysis, positioning self-efficacy as the independent variable and students' usage behavior as the dependent variable (Table 19).

Table 19: Results of testing Null Hypothesis H1.6.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.033 ^b	4.307	.985	.418 ^a	0.174	970	Rejected Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics (P=0.033) is less than the level of significance (0.05). Based on this, the null hypothesis is rejected, thus there is a significant relationship between self-efficacy and students' usage behavior. Moreover, it is shown in the table that the correlation coefficient (R) between Self-efficacy and students' usage behavior is moderate at (0.4186). Thus, self-efficacy has a moderate positive role in students' usage behavior.

Anxiety - Usage Behavior relationship (H1.7):

Testing H1.7: Lower levels of anxiety while using computational design tools will positively affect students' usage behavior towards using computational design tools.

H1.7 emerges as a focal point in our exploration of architecture design students' engagement with Computational Design (CD) tools. This relationship asserts that lower levels of anxiety while using CD tools positively influence students' usage behavior. To rigorously assess this claim, our analytical approach involves regression analysis, setting anxiety levels as the independent variable and students' usage behavior as the dependent variable (Table 20).

Table 20: Results of testing Null Hypothesis H1.7.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.043 ^b	7.200	.728	.019 ^a	0.17	0531	Rejected Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics ($P = 0.43$) is less than the level of significance (0.05). Based on this the null hypothesis is rejected, thus there is a relationship between anxiety and students' usage behavior. Moreover, the table displays that the correlation coefficient (R) between anxiety and students' usage behavior is weak at (0.019). Thus, we can say that anxiety has a weak positive role in students' usage behavior.

Main hypothesis: Usage Behavior - Behavioral Intentions hypothesis (H1):

Testing H1: Positive usage behavior towards computational design tools will have a significant positive influence on students' behavioral intention to use the tools in the architecture practice after their graduation.

Hypothesis H1 postulates that positive usage behavior towards CD tools significantly influences students' behavioral intention to use these tools in their architectural practice post-graduation. To rigorously scrutinize this hypothesis, our analytical focus shifts to regression analysis, where positive usage behavior is designated as the independent variable, and behavioral intention becomes the dependent variable. This analysis seeks to unveil the extent to which students' positive experiences with CD tools during their education shape their future intentions in the professional

realm. Through this investigation, the aim is to contribute crucial insights into the intersection of usage behavior, intention, and the integration of technology in architectural practice (Table 21).

Table 21: Results of testing Null Hypothesis H1.0

Sig.	Calculated T	Scheduled T	Correlation R	R Square	F	Decision
.036 ^b	8.951	.199	.431 ^a	0.200	.341	Rejected Null Hypothesis

The table shows that calculated (t) is bigger than scheduled (t), and the probability of (F) statistics (P= .036) is less than the level of significance (0.05). Thus the null hypothesis is rejected, and therefore there is a relationship between usage behavior and behavioral intention with CD tools. Moreover, the same table shows that the correlation coefficient (R) between usage behavior and behavioral intention with CD tools is moderate at (0.431). Hence it is concluded that usage behavior has a moderate positive role in behavioral intention with CD tools.

5.5 Hypotheses Results Discussions

This section discusses the results revealed from hypotheses testing to address the research's main question: What are the critical behavioral, technological, and environmental factors that affect students' usage behavior, which in sequence affect their behavioral intentions to use the system in the future? Table 22 summarizes the outcomes of the hypotheses and compares them to the results of the UTAUT model [37].

Table 22: Hypotheses conclusions summary

Hypotheses	Independent Variable	Dependent Variable	Thesis's Results	Strength of the correlation	UTAUT's Results
Main hypothesis: H1	Usage behavior	Behavioral Intentions	Supported	moderate	Behavioral Intentions has direct influence on Usage behavior
H1.1	Performance expectancy	Usage behavior	Supported	weak	Direct Influence
H1.2	Effort expectancy	Usage behavior	Not supported	-	Direct Influence
H1.3	Social influence	Usage behavior	Supported	moderate	Direct Influence
H1.4	Facilitating conditions	Usage behavior	Supported	moderate	Direct Influence
H1.5	Attitude	Usage behavior	Not supported	-	Indirect Influence
H1.6	Self-efficacy	Usage behavior	Supported	moderate	Indirect Influence
H1.7	Anxiety	Usage behavior	Supported	weak	Indirect Influence

5.5.1 The influence of UTAUT factors on students' usage behavior

System usage is a key variable in many research in IS context [37]. In this research, seven factors from the UTAUT model were empirically tested to analyze their influence on students' usage behavior. Then, usage behavior's relationship with behavioral intentions was tested.

The result of this study revealed that Social influence, Facilitating conditions, and Self-efficacy are proven to have a moderate influence on usage behavior. While Performance expectancy and Anxiety, have a low effect on usage behavior. Effort expectancy and Attitude are proven not to have any influence on usage behavior.

Lastly, it is found that usage behavior has a moderate influence on students' behavioral intention regarding using CD tools post-graduation. The following paragraphs provide more details for each factor. A summary of the results is presented in Table 5.

a. Performance Expectancy: Through the verification of CD tools usage behavior and behavioral intention model, it was found that (PE) has a positive influence on students' usage behavior, however, this relationship was found to be weak.

This result is not entirely similar to the finding from the UTAUT model, as Venkatesh et al. [37] found that there is a strong and direct relationship between (PE) and usage behavior. Although the influence of PE is weak, it still exists. Other studies found that (PE) influences user behavior toward a technology system [216]-[220].

Despite the findings of the descriptive analysis of (PE) items which indicated that most of the students perceive the CD tool as useful (Table 5), the influence of this factor on their usage behavior is weak.

b. Effort Expectancy: it was hypothesized that (EE) positively affects students' usage behavior. However, the findings of the hypothesis test revealed that (EE) plays no role in students' usage behavior toward CD tools. This result is inconsistent with the finding of UTAUT which indicated that (EE) has a direct influence on Usage Behavior. However, our result is consistent with other studies that found that effort expectancy has no direct influence on the usage behavior of a technology system [225], [226]. Although most of the students have a positive opinion about the Effort Expectancy (easiness) of using CD tools, as shown in the descriptive analysis of (EE) items (Table 6), there is no role of (EE) on design students' usage behavior toward these tools.

c. Social Influence: This research hypothesized that (SI) will positively affect students' usage behavior. This hypothesis was supported based on the findings. The findings revealed from the statistical test that a moderate relationship between (SI) and students' usage behavior toward CD tools was indicated.

This result in a certain manner is consistent with the findings of the UTAUT model, as Venkatesh et al. [37] found that there is a strong and direct relationship between (SI) and usage behavior. Other previous studies have also shown that (SI) has a positive influence on usage behavior [221], [223], [226], [227].

In addition, the findings of the descriptive statistics of (SI) items showed that most of the students perceive that they are affected by the social environment regarding utilizing CD tools (Table 7).

d. Facilitating Conditions: This research argued that (FC) will influence students' usage behavior positively. Based on the hypothesis testing, the finding showed that this hypothesis is supported and has a moderate effect on students' usage behavior.

The result of this hypothesis is somehow coherent with the finding of the UTAUT model, as it was concluded in the model that (FC) has a strong effect on usage behavior. Moreover, several studies showed that there is a correlation between facilitating conditions and user behavior toward a technology system [40], [220], [226], [227].

In addition, this hypothesis result is also consistent with the descriptive statistics finding of (FC) items which revealed that most of the students think that necessary resources and training are available during their study (Table 8).

e. Attitude: The proposed hypothesis regarding attitude argued that usage behavior is influenced positively by students' positive attitudes. This hypothesis was not

supported based on the findings of the analysis. It was concluded that there is no effect of (AT) on students' usage behavior.

The result of the attitude hypothesis is consistent with the one proposed by the UTAUT model as it considers user attitude toward a technology to be indirect. In addition, a study by Howard et al. [40] found that there is no significant relationship between attitude and behavioral intentions. Although most of the students have a positive attitude toward CD tools, as shown in the descriptive analysis of (AT) items in (Table 9), there is no role of (AT) on students' Usage Behavior.

f. Self-Efficacy: This thesis hypothesized that (SE) has a positive influence on students' usage behavior. This argument was supported by the findings of the analysis. It was found that (SE) has a moderate positive effect on students' usage behavior. This result contradicts the UTAUT model, which considered (SE) as an indirect factor. However, this hypothesis result is consistent with other studies that concluded that (SE) affects usage behavior [218], [232]-[234].

This result is also confirmed by the descriptive analysis of (SE) items. The findings showed that most of the students have high self-efficacy (Table 10).

g. Anxiety: This research argued that levels of anxiety will positively affect students' usage behavior toward CD tools. This argument was supported, as the findings of the analysis revealed that there is a relationship between (A) and usage behavior. However, the correlation between them is weak.

In this case, we consider that the result is inconsistent with the UTAUT model that suggested that (A) is an indirect factor. This is because it was revealed that there is an

influence of (A) on User Behavior, but it is weak. However, our result is consistent with a study by Delcourt & Kinzie [232], who found a weak-moderate effect of (A) on the use of the computer. In addition, a study by Thatcher & Perrewé [235] found that there is an effect of (A) on the usage of a technology system. The result of this hypothesis is also consistent with the descriptive analysis of (A) items in (Table 11). It was shown that most of the students have lower levels of anxiety towards CD tools.

The influence of usage behavior on behavioral intentions

In the UTAUT model, the behavioral intentions factor was determined to be the independent variable, and usage behavior was the dependent variable. However, in this research, the proposed model was to determine usage behavior as an independent variable. This modification was done because most final-year architecture design students have some experience in utilizing CD tools. Therefore, the Behavioral intentions factor was determined to be the dependent variable to test students' intentions to use the tools post-graduation.

Therefore, it was argued in this thesis that Positive usage behavior will have a significant influence on students' behavioral intention to use CD tools after graduation. The statistical analysis revealed that this hypothesis is supported and there is a moderate positive influence on students' behavioral intentions.

Therefore, it can be interpreted that most of the factors (PE, SI, FC, SE, and A) affect usage behavior which in sequence has a moderate influence on design students' usage behavior, while (EE) and (AT) do not influence Usage Behavior.

CHAPTER VI

CONCLUSIONS

This study was conducted to evaluate final-year architecture design students' usage behavior and behavioral intentions toward using computational design tools. It also explored the behavioral, technological, and environmental factors that affect their behavior.

Social Influence, Facilitating Conditions, and Self-efficacy were found to exert a moderate influence on students' usage behavior. Performance Expectancy and Anxiety, on the other hand, exhibited a low impact on usage behavior. Effort Expectancy and Attitude were determined to have no significant influence on students' usage behavior. The findings regarding Performance Expectancy contradicted some expectations, showing a weak positive influence on usage behavior. Effort Expectancy, despite positive perceptions, did not play a role in shaping students' usage behavior. Social Influence, Facilitating Conditions, and Self-efficacy demonstrated moderate effects, aligning with the UTAUT model. Attitude, despite positive attitudes among students, was revealed to have no impact on their usage behavior. Self-Efficacy was found to have a moderate positive effect on students' usage behavior, indicating its importance in influencing their behavior. Anxiety, which was hypothesized to have a positive influence on usage behavior, showed a weak correlation, suggesting that while anxiety exists, its impact is limited. This finding deviates from the UTAUT model, which

considers anxiety as an indirect factor. The overall model indicated that Positive Usage Behavior has a moderate influence on students' Behavioral Intentions to use computational design tools post-graduation. This shift in perspective, with Usage Behavior as the independent variable and Behavioral Intentions as the dependent variable, provided valuable insights into students' intentions to use these tools in their future careers.

The proposed research model was formulated based on The Unified Theory of Acceptance and Use (UTAUT), in which seven factors are determined to influence architecture design students' behavior. Performance expectancy, Effort expectancy, Social influence, facilitating conditions, Attitude, Self-efficacy, and Anxiety were determined to be independent variables. Usage behavior is the mediating variable that transmits the effect of the independent variables on the dependent variable. Usage behavior is considered an independent variable that influences Behavioral intentions.

A quantitative approach was employed to collect the data, assess a set of hypotheses, and examine research variables using statistical analysis techniques. A questionnaire survey was utilized based on the UTAUT model which was developed and assessed through the analysis of quantitatively collected data. UTAUT is a highly influential and robust model for comprehending the usage of technology systems.

The data was collected from the opinions and perceptions of 30 students from the Department of Architecture at Özyeğin University. The summary of the observed results indicated that Social influence, Facilitating conditions, and Self-efficacy were proved to have a moderate influence on design students' usage behavior. While for

Performance Expectancy and Anxiety, it was proved that they have a weak influence on usage behavior. Effort Expectancy is not influencing Usage behavior, contrary to what is presented in the literature. In addition, Attitude does not have any influence on students' usage behavior. Finally, the model revealed that there is a positive relationship between Usage behavior and Behavioral intentions.

This research intended to provide three contributions to the literature: firstly, this thesis emphasized studying the individual (user level) in the context of architectural design education as few computational design tool-related studies have delved into this perspective. Secondly, this thesis evaluates the behavioral, technological, and environmental factors, which can have an important effect on the behavior related to the use of a certain technology. Finally, this study intended to offer insights for educators into the direct and indirect factors that influence usage behavior, aiding them in making suitable decisions regarding the architectural design curriculum.

This study involved several limitations. Firstly, the study range is restricted to Özyeğin University, thus these findings may not be generalized to all universities in Turkey. Secondly, the findings might be influenced by self-selection bias. Thirdly, the study did not test a wider range of demographic characteristics such as age and experience duration, as most of the participants are of the same age and have similar experience durations. Fourthly, the study mainly focused on the factors suggested by the UTAUT model; however other factors may considerably influence students' usage behavior and behavioral intentions. In addition, one of the limitations of this study is related to computational design tools that are utilized by the students at Özyeğin

University, as it was shown that most of the students use mainly AutoCAD and SketchUp, thus the results cannot be generalized to cover other CD tools. Finally, this research is based on a statistically validated hypothesis suggested by UTAUT.

This research is conducted based on the UTAUT model which has a significant contribution to explanations of users' behavior. However, this model does not take into account students' learning abilities and educational methods. Future research might focus on including additional variables related to learning abilities and methods. In addition, future work might consider widening the sample to include more universities in the study. This will draw better general conclusions regarding students' usage behavior and behavioral intentions toward CD tools.

In conclusion, this research tended to contribute to set initial work for exploration and understanding of architectural design students' behavior toward utilizing computational design tools in the context in question.

APPENDIX A

Table 23: Items of section A of the questionnaire

Category	Question
Students' experience duration, and skill level.	1- As a design student, do you prefer using CD tools in your curriculum design projects?
	2- How do you rate your skills in using CD tools in your design projects in general?
	3- How long ago did you start learning and using CD tools?
	4- How do you rate your skills in CD tools? (AutoCAD, ArchiCad, Ecotect, 3DMax, Dynamo, Microstation, Revit, Maya, Grasshopper, Rhinoceros, 3D SketchUp)?
	5- How did you obtain your experience in using CD tools?

Table 24: Items of section B of the questionnaire

Category	Question
Performance expectancy H1.1: Performance expectancy will positively affect students' usage behavior towards using computational design tools.	1. I would find using CD tools useful in my design projects.
	2. Using CD tools enable me to accomplish my design task more quickly.
	3. Using CD Tools increase my productivity.
	4. By using CD tools, I will increase my chances of coming up with better/ more creative designs.
	5. The use of CD tools consumes less time compared to conventional design tools.
	6. Using CD tools give me greater control over my design.

	7. Using CD tools in curriculum design projects have improved my architectural design skills compared with traditional tools.
Effort expectancy H1.2: Effort expectancy will positively affect students' usage behavior towards using computational design tools.	8. CD Tools are clear and understandable.
	9. It is easy for me to become skillful at using CD tools.
	10. I find CD tools easy to use in my curriculum design projects.
	11. I learned how to use CD tools quickly.
	12. I would find CD tools to be flexible to use
Social influence H1.3: A high level of social influence will positively affect students' usage behavior towards using computational design tools	13. It is easy for me to remember how to perform tasks using CD tools.
	14. I use CD Tools because I got influenced from the students around me.
	15. The studio master in design course has been helpful in encouraging the use of CD tools.
	16. The social environment of the studio has supported the use of CD tools.
	17. I feel pressured to use CD tools in design projects because everyone uses them.
Facilitating conditions H1.4: A high perceived level of facilitating conditions will positively affect students' usage behavior towards using computational design tools	18. Students in studio who use CD tools have more prestige than those who do not.
	19- I have the necessary resources to use CD tools.
	20- I have learned and trained with the necessary knowledge to use CD tools.
	21- Guidance from a specific person or group was available to me to assist me with CD tools difficulties.
	22- As a final-year student, I think that the period of previous semesters was enough to learn using CD tools professionally.
Attitude H1.5: Positive attitude toward computational design tools will positively affect students' usage behavior towards using	23- As a final-year student, I think that the period of previous semesters were enough to gain an intermediate level of using CD tools.
	24- CD tools make designing more interesting
	25- Designing with CD tools are fun and enjoyable.
	26- I like using CD tools in my curriculum design projects.
	27- When using CD tools I feel more confident with my design.

computational design tools	28- CD tools give me the courage and motivation to accomplish the design project.
	29- I am satisfied with using CD tools in my design project.
Self-efficacy H1.6: High level of self-efficacy in using computational design tools will positively affect students' usage behavior towards using computational design tools	30- I can recover from mistakes quickly and easily while using CD tools.
	31- I can solve most problems without someone around to tell me what to do as I go.
	32- Whatever comes my way while using CD tools, I can find the solution without calling for assistance or access to support videos
	33- I believe I have enough knowledge on how to use CD tools in my curricular design projects.
	34- I can use CD tools in my design projects with ease and proficiency.
	35- I can complete a task using CD tools without asking for extra time.
	36- When I am confronted with a problem, I can usually find several solutions.
	37- When I design with CD tools I can easily achieve the desired design that I want.
	38- I am confident that I could deal efficiently with unexpected events while using CD tools.
Anxiety H1.7: Lower levels of anxiety while using computational design tools will positively affect students' usage behavior towards using computational design tools	39- As a final-year student I still feel anxious about using CD tools.
	40- As a final-year student I still feel scared of doing mistakes while using CD tools.
	41- As a final-year student I hesitate to use the system for fear of making mistakes I cannot correct
	42- I can't control my anxiety when I face an issue during the use of CD tools in my design project

Table 25: Items of section C of the questionnaire

Category	Question
Mediating Variable: Usage Behavior	1- How often do you use CD Tools in your curriculum design project?
	2- When you work on your design project, do you switch between CD Tools?
	3- Do you tend to use CD Tools as a drafting tool or as a design tool?
	4- Do you tend to use "CD Tools" alongside with “traditional tools” in your curriculum design projects?
	5- In which stage(s) of the design process do you use CD Tools?
Dependent variable: Behavioral Intention	6- I plan to use CD Tools in design projects after graduation, in the architectural field.
	7- I believe I have enough knowledge on how to use CD Tools in my curricular design projects.
	8- I plan to learn more tools to use them in the field after graduation.
	9- I am concerned in improving my skills in CD Tools.
	10- The knowledge and training on using CD Tools that I gained in my bachelor is enough to support me in the architecture field

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