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Modeling the Critical Factors Affecting the Success of Online Architectural Education to Enhance Educational Sustainability

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Abstract: Due to their unique requirements, the COVID-19 pandemic precipitated an urgent shift toward online education, profoundly impacting disciplines such as architectural education (AE). While online education has demonstrated efficacy in theoretical domains, practical disciplines like AE face significant challenges, particularly in design studios (DS). This study aims to identify the critical factors affecting the success of online architectural education for sustaining educational quality amid crises. A comprehensive systematic literature review was undertaken, followed by the development of a questionnaire encompassing 53 challenges pertinent to online architectural education (OAE). The questionnaire was administered to architecture students who had experienced OAE, resulting in 232 fully completed responses. Twenty-four critical challenges (CCs) were identified through normalized mean value analysis. Exploratory factor analysis revealed three pivotal factors, subsequently validated by confirmatory factor analysis. A structural equation model (SEM) was constructed to elucidate the magnitude of impact exerted by these critical factors on the success of OAE. Critical challenge factors encompassed obstacles to (1) interactive, communicative, and collaborative social learning, (2) inexperience and technical constraints, and (3) enhanced accessibility, and self-sufficiency. These findings represent a first and novel contribution to this domain, distinct from previous research endeavors, by delineating the primary factors critical to the success of OAE.

Keywords: architectural education; critical challenges; structural equation modeling; sustainable education; online education

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1. Introduction

The COVID-19 pandemic has prompted a widespread shift in societal norms, leading humanity to embrace alternative ways of life [1]. In response, authorities worldwide have been compelled to implement critical precautions to ensure the safety and well-being of their communities [2]. This situation has necessitated significant adaptations across various sectors, including education, as institutions strive to accommodate these measures [3]. As an initial response to the COVID-19 pandemic, the suspension of face-to-face education was widespread worldwide to curb the spread of the virus [4]. Consequently, all educational institutions swiftly transitioned to online mode to ensure the sustainable provision of education. However, this shift profoundly impacted the education system, emerging as one of the sectors hardest hit by the pandemic [5], affecting all education stakeholders due to the disruption of traditional learning methods.

Online education is recognized as a novel learning system, which was tried to adopt as the internet's popularity grew during the 2000s, with no compelling circumstances. On the other hand, online education was adopted as a long-term and balanced solution to mitigate the challenges posed by COVID-19. However, despite its implementation, this novel educational method proved insufficient in fully mitigating the issues caused by the pandemic, particularly in practice-based disciplines with specific demands, such as architectural education (AE) [1,6–9].

While online education methods have demonstrated effectiveness across numerous domains [10], specific fields, including AE, encounter unique challenges. Former studies highlighted several challenges using simple statistical analysis, including lack of tutorials' support and assessment [8,11], privacy concerns [6], poor internet connectivity [1], technical and technological difficulties [1,6,8,12,13], design process challenges [14,15], communication and interaction disruption [8,11], nature of online education [12], lack of time and potential interruption, and extended studying time [6,12,13].

After thoroughly reviewing pertinent literature, challenges associated with online architectural education (OAE) were identified, each of which holds significance. However, discerning the critical challenges is crucial for sustaining AE remains to be determined. Knowledge of these primary factors is essential for instituting preventive measures and mitigating adverse consequences. In light of this, this study attempts to pinpoint the critical challenge factors impeding AE's sustainability and devise a model for assessing the degree of influence exerted by each factor on educational success. Potential challenges were extracted from the literature through a systematic review to achieve this objective. Subsequently, a questionnaire incorporating these challenges was administered to architecture students to collect data. Despite numerous challenges documented in the literature on OAE, identifying the critical ones has remained elusive. Hence, critical challenges were ascertained utilizing normalized mean values. These critical challenge factors were further elucidated through exploratory and confirmed via confirmatory factor analyses. Finally, a structural equation model was constructed to develop an integrated framework linking critical challenge factors, thus distinguishing this study from prior research endeavors.

2. Navigating the Shift: Theoretical Foundations of Online Architectural Education

AE is the initial stage where fundamental professional training is provided, laying the foundations for the commencement of professional practice. Primarily characterized by experiential learning, AE distinguishes itself from other methods by emphasizing skill acquisition [16]. It involves a series of engagements that foster a dynamic exchange between the instructor and the student, facilitating visual and auditory communication to enhance the learning process [17]. In this process, the instructor demonstrates through drawing and practical engagement while the student observes and listens, interpreting the conveyed information to develop their proposals. This cycle persists through the instructor's critique of the student's suggestions. Schön [16] refers to this feedback loop as "reflective practice". This dynamic involvement and co-creation between student and instructor are active learning, as supported by scholars [7,17].

The distinctive structure of AE shows the need for a learning environment prioritizing face-to-face hands-on learning and collaborative engagement among students within studio settings, which is crucial for an effective educational process. However, the unforeseen outbreak of the COVID-19 pandemic in 2020 rendered this unfeasible.

Architecture departments transitioned to online learning to prevent the spread of COVID-19 and ensure the continuity of education, as in all academic departments. However, this transition could have been more effective, as AE is not merely the conventional instruction acquired through training [18]. Each field of education possesses distinct attributes, needs, and an underlying philosophy [17]. While specific disciplines rely heavily on lectures, others prioritize collaborative efforts and close engagement among participants. The shift to online education has introduced additional challenges, especially in disciplines that rely on requirements. Therefore, architectural programs, which typically encompass theoretical and practical courses, have been significantly impacted by this transformation, as they involve various aspects such as physical gatherings, collaborative work, and specialized approaches.

Within this context, the COVID-19 pandemic has compelled pedagogy professionals to reassess AE by utilizing familiar methods and exploring new potentials [19]. This initiative has demonstrated that AE can be effectively conducted using alternative methods and tools. However, there is ongoing debate regarding integrating technology-based methods into AE, particularly concerning the organization and characteristics of course designs [2]. Indeed, while high levels of information and communication technologies (ICT) and digital learning tools have been effectively adopted in theoretical courses, challenges have arisen in implementing these tools in practical courses, where hands-on experience and physical engagement are integral to the learning process [5].

Typically, the educational process in AE involves teaching problem-solving skills and identifying the problems themselves [5]. Thus, the collaborative nature of AE fosters the generation of creative and innovative solutions to various challenges. Additionally, AE has its requirements and differs from practice and education in other disciplines [20]. However, by the nature of these needs, they cannot be met in online education, like learning by doing [18], ensuring intense interaction and effective communication between students and instructors [1,7,9], and peer learning [2,21]. These specific needs are especially acute in the design studio (DS), which forms the core of AE [7,17,22,23].

Several supplementary courses contribute to enhancing AE's educational outcomes. Among these, DS is a unique course that sets AE apart from other disciplines. Furthermore, when examining the various courses within AE, it becomes evident that DS is undoubtedly the most fundamental [2]. This distinction arises from the studio environment's characteristic emphasis on experiential learning of architecture.

The DS, a series of successive courses, holds a central position with significant focus and importance in AE [24]. As the core of AE, it integrates theoretical and technical knowledge acquired from other courses with skill development exercises in design [17]. DS courses are a common feature in most architectural programs, often fostering collaborative environments due to the open-ended nature of the design process and the complexity of building designs [25–27]. These studios provide students with multidimensional spaces to create, interact, discuss, and share their design work with peers [7,20]. Schön [18] emphasized the pivotal role of learning within the DS, highlighting it as the primary activity in AE. Therefore, meeting the requirements of AE outlined above is crucial for success in the DS. However, the demands of the discipline, easily accommodated in face-to-face AE, pose significant challenges in online architectural education (OAE) settings [2,8,28,29].

Consequently, the abovementioned issues have emerged as the most significant challenges in the transition to OAE, sparking ongoing debate worldwide. The success of OAE has come under scrutiny due to its inability to meet the specific requirements of AE outlined earlier. Researchers from various countries, including India [1,9,11], Serbia [14], Jordan [6,7,22], Iran [8], Egypt [30], Saudi Arabia [31], England [15,21], the USA [32,33], Australia [34,35], and Poland [36], have conducted research on these issues in the field of OAE and have consistently evaluated this method.

However, success factors for both types of courses in OAE need to be evaluated more thoroughly compared to conventional face-to-face AE. Based on this observation, current research concludes that identifying the critical factors hindering OAE's success will address these shortcomings and contribute to the sustainability of AE during possible future crisis periods. Therefore, the current study aims to determine the steps AE should take regarding online learning in the post-pandemic era to ensure a sustainable future.

3. Research Background and the Literature Gap

Architecture is vital in comprehensively addressing environmental issues, particularly in developed countries [37]. Accordingly, architectural education (AE) has evolved alongside global educational progress and sustainable development. Many organizations emphasize architects' unique ability to contribute significantly to sustainable development goals [38]. Since buildings account for 39% of global energy-related carbon emissions and 40% of extracted materials are utilized in construction, sustainability is pivotal in AE [39]. Thus, a global demand exists for integrating sustainable AE into academic curricula, aiming to equip present and future architects with the knowledge and skills for more sustainable architectural practice [40,41]. Consequently, numerous architecture schools have incorporated sustainable architecture into their teaching programs [42].

There is compelling evidence that high-quality infrastructure enhances teaching effectiveness and boosts student achievement, among other advantages. Therefore, architectural education (AE) varies significantly between developed and developing countries. In developed countries, there is a focus on modernizing the architectural curriculum to facilitate sustainable development, incorporating principles of sustainability and energy efficiency [43,44]. Additionally, there is an emphasis on the responsibility of AE for the sustainability of the built environment, with a need to address the challenges of coping with the relationship between heritage and sustainability [45,46]. Furthermore, there is an acknowledgment of the importance of educating students about historical traditions and global culture in AE [47].

On the other hand, in developing countries, there may be different challenges, including economic growth, sustainability, creativity, productivity, and cultural dynamics. The impact of higher education on economic growth in developing countries, particularly in ASEAN-5 countries, has been studied, revealing that higher education impacts become stronger when enrollment rates exceed a certain level [48]. Additionally, integrating sustainability within AE has been identified as a challenge, particularly in addressing the dichotomy between creative expression and technical exploration, which is essential for high-quality sustainable design [49].

Cultural and environmental factors also play a significant role in architectural education in developing countries. Place-based education has been explored to include a broader spatial-cultural context in architectural design, prioritizing environmental literacy and responsibility as components of sustainable development [50]. Additionally, the effects of social, cultural, and educational dynamics on the education-training environment in AE have been studied, emphasizing the importance of these dynamics in shaping the learning experience [51].

These differences may stem from institutional and school characteristics and individual and family characteristics, which impact educational achievement at pre-university levels [52]. Given the heterogeneous levels of development across countries, a standardized global framework needs to be standardized. Therefore, it is essential to consider developing countries' specific needs and contexts when addressing AE.

AE has been compelled to face the evolving landscape of online education due to the new circumstances brought about by educational suspension, leading to a redefinition of educational paradigms in both developed and developing countries [30]. While it appears likely that teaching and learning will continue to involve technology via a distance model in the post-pandemic world [2], there are concerns about the pandemic's long-term effects on AE, particularly the inheritance of "emergency strategies" used to teach online [35]. Also, Hodges et al. [53] stated that well-planned online learning experiences differ from online courses in response to a crisis or disaster. However, the transition to online teaching in DS and other courses without sufficient resources and experience has had a drastic technological [1,14], psychological [2,54], economic [36,55], and pedagogical impact [4,32] on learning and teaching modes in AE. Therefore, this occasion has attracted the attention of several scholars from various countries. Some scholars have concentrated on the impact of OAE [56], OAE adaption [9,22,31], and the transformation of AE [23,57]. Moreover, most researchers have determined architecture students' perceptions and challenges of OAE [6–8,11,14,17,36]. In addition, the blended learning strategy for AE [2] is another topic studied in this domain.

On the other hand, several methodologies have been utilized in former studies. These include conducting online surveys of architecture students and employing descriptive statistics for data analysis [1,15,58,59]. Exploratory factor analyses have been conducted in some studies [8], while others have employed the analytic hierarchy process [60]. Additionally, qualitative analyses or mixed methods have been adopted in various studies, incorporating semi-structured interviews and online surveys [2], experimental studies [61], surveys, case studies, and structural equation modeling [4], as well as focus group interviews, questionnaire surveys, and statistical analyses [6]. Furthermore, bibliometric and content analyses were conducted [5].

In developing countries, the impact of OAE has highlighted the importance of assessing students' and instructors' satisfaction with online education, particularly in developing country contexts [62]. The shift to online classes has posed specific challenges for AE, primarily due to its reliance on the social studio setting, which has been a significant challenge in the new normal of online education [63]. Furthermore, experiences from specific institutions, such as the Mehran University of Engineering and Technology in Pakistan, have shown that while theoretical classes can be effectively taught online, practical/studio work in architecture is more challenging to deliver in an online format [64].

AE in developing countries also faces challenges adapting to online learning, as evidenced by the evaluation of online architectural design studios during the COVID-19 outbreak [17]. The transition to online education has raised concerns about student engagement and motivation, especially when studio projects are detached from context or reality [65].

While the above qualitative and quantitative studies have significantly contributed to our understanding of the OAE domain, no study has quantified how pandemic factors affect the AE in Turkey. However, it is essential to note that despite these contributions, numerous aspects within this domain still require further investigation. Therefore, the current study identifies the main pandemic factors and their impact on AE in Turkey. In this context, the challenges of the OAE are derived from a systematic literature review (SLR). Normalized mean values (NMV) were performed to determine the criticality of challenges. Exploratory (EFA) and confirmatory factor analyses (CFA) were used to identify major pandemic factors. Lastly, the interconnection among the structural pandemic factors was cross-checked and an integrated factor model was developed using structural equation modeling (SEM). The developed model is the primary contribution of this research.

The above studies show that

(1) Previous studies have yet to determine the critical challenge factors of OAE that, quantitatively and qualitatively, hinder its success;
(2) No study highlights the most influential factors.

Therefore, three leading aspects represent a knowledge gap: (1) determining critical challenge factors hindering the successful OAE can clarify the current and potential consequences of the OAE. (2) Modeling the critical challenge factor effects may explain the significance of each factor(s) for the OAE. Moreover, a modeling strategy can help implement actions to overcome the challenges faced by the pandemic. Finally, (3) this study addresses the research and knowledge gap by determining the critical challenge factors of OAE in Turkey, which can be generalized to almost all developing countries.

Determining the pandemic-experienced factors affecting the AE over the long term is critical for sustainable education. To fill the existing research gap in the literature on OAE, it is essential to determine the critical challenge factors hindering its success and model them, aiming to highlight the effect size of each determined factor on its success.

4. Research Methodology

The current study employed a comprehensive research approach to identify and examine the pivotal obstacles impacting the efficacy of OAE. The methodology framework is depicted in Figure 1. The investigation begins with a systematic literature review to pinpoint architecture students' challenges. Subsequently, a questionnaire is devised as the primary assessment tool. After this, data are collected via an online survey to mitigate transmission risks. The collected data underwent initial reliability analysis. After this, critical challenges were determined through normalized mean value ranking. An exploratory factor analysis then unveiled the crucial factors. Finally, these critical factors were delineated and modeled via a structural equation model.

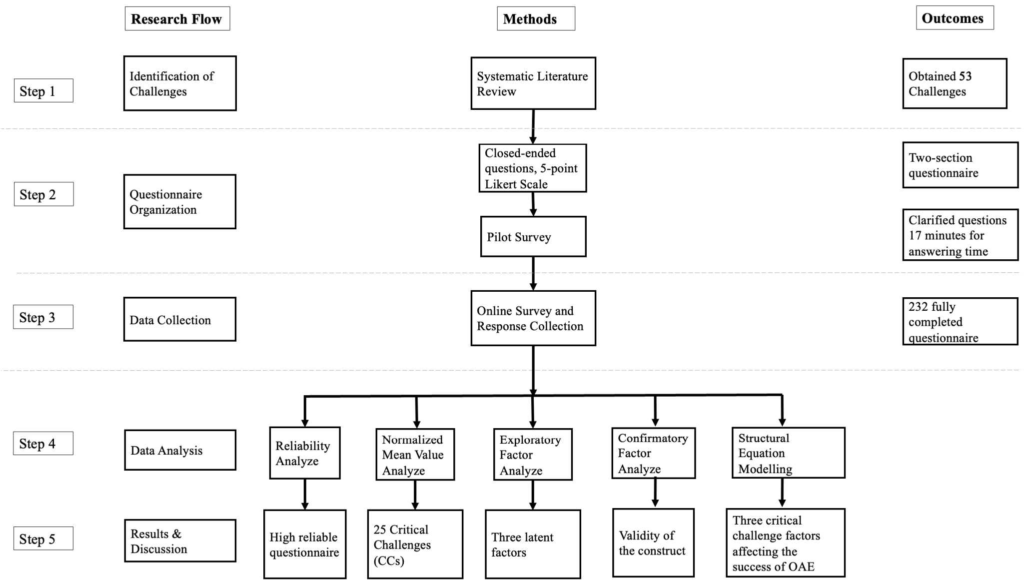

Figure 1. Flow diagram of the research protocol within the scope of SLR.

4.1. Determining Challenges of OAE

The initial phase of this study involved identifying the challenges associated with OAE that impact its success. A systematic literature review (SLR) was employed, recognized as a method-driven, transparent, and repeatable technique, as elucidated by Booth et al. [66]. SLR systematically analyzes and comprehensively understands all relevant research on a particular issue, subject, or phenomenon [67,68]. Unlike citation-based approaches, SLR offers a robust means of evaluating published work within a scientific domain.

The Web of Science (WoS) database encompasses nearly all primary research articles, so it was utilized to locate scientific papers pertinent to OAE. The search was confined to articles in English from 2000 to 2022. The screening started in 2000 because the internet's popularity grew during the 2000s and several attempts were made to adopt OAE. Therefore, some pioneering studies have been conducted in this domain since 2000. To avoid ignoring these significant studies and their outputs, the search was conducted from 2000 onward; keywords delineated search criteria within the Web of Science (WoS) database, spanning all fields. The specified search parameters were defined as follows: "architectural education" AND "online learning" OR "distance education" OR "distance learning" OR "online learning" AND "COVID-19".

The search initially identified 465 journal articles, narrowed to 395 by filtering for specific WoS categories, namely architecture and education educational science. Nine records were excluded due to language differences.

Subsequently, two independent authors assessed 386 full-text studies. Studies were excluded if their aims were irrelevant or did not align with online architectural education. Out of the 386 full-text studies, 342 irrelevant ones were eliminated. The remaining 44 papers underwent a coding process wherein the key findings of each study were linked to specific challenges. This process led to the identification of 53 challenges. These challenges were analyzed according to their scope and impact, as some share similar characteristics. The aim was to identify the main themes by expanding the dimensions of the criteria. Subsequently, the obtained criteria were further organized, considering their content and emerging features. These were then grouped into themes and labeled according to the characteristics highlighted by the criteria 'technical and technological infrastructure', 'health and psychology', 'interaction, communication, and satisfaction', and 'educational adaptation'. It is observed that the criteria within these themes intersect, forming a cohesive framework. This categorization was based on their impact, scope, and focus, aiming to understand the factors at play comprehensively. The definition and categorization of challenges considered their respective impact areas and are presented in Table 1.

Table 1. Challenges of OAE.

Classification	Code of Challenges	Challenges	Source
Technical and technological infrastructure	C1	Lack of an adequate technical background to solve networking and software-related issues	[13,32,69]
	C2	Technical issues	[2,21,30,36]
	C3	Lack of fast and stable internet connection	[6,7,11,13–15,21,29,30,36,56,70,71]
	C4	Low-screen resolution quality—the screen resolution makes it difficult to see the design work in detail	[54,71,72]
	C5	The emergence of cyber security risks	[21,55,73,74]
	C6	Insufficient screen resolution to accurately display and critique scaled drawings	[36,54,72]
	C7	Lack of the possibility of drawing or sketching on the screen; difficulties with using the mouse for sketching	[4,30,36,54]
	C8	Issues with the availability of up-to-date and appropriate hardware and software platforms	[1,4,9,13–15,29,32,54,73,74]
	C9	The need for user-friendly interfaces and applications to make e-learning easy	[7,9,74]
Health and psychology	C10	Lack of guidance and support	[7,8,22,30,33,73]
	C11	Lack of privacy (felt by both teachers and students)	[6,8,12,30,74]
	C12	Time and workload management (i.e., an increase in the number of tasks)	[1,6,7,11,30]
	C13	Increased sense of isolation and disconnection from peers and colleagues	[2,13,30,32,54,75]
	C14	Psychological problems/negative feelings that could lead to alienation, uncertainty, confusion, and identity loss	[2,6,7,15,17,22,28,32]
	C15	The dissolved boundaries between the work environment and home environment (i.e., struggle with establishing boundaries between work and family)	[2,6,55,56]
	C16	When feedback is delayed, students feel stress, frustration, and confusion	[7,30,33,72]
	C17	The lack of emotional connection	[4,7,30,32,76]
	C18	Insufficiency of self-discipline and concentration issues	[1,9,11,21]
	C19	Extended working hours for instructors	[2,7,56]
Interaction, communication, and satisfaction	C20	Instructors need help to keep students concentrated throughout the lesson	[1,6,31,56,73]
	C21	Instructors are struggling to motivate students to ask question	[31,32,56,73]
	C22	Students are deprived of this opportunity because the university cannot create a campus culture and university spirit online	[28,32,73]
	C23	Participants' designs and presentations become rather dull without facial expressions and body language	[30,71,73,77]
	C24	Expectations from students to be more responsible for their education	[7–9,17,22,28–30,33,35,57,69]
	C25	Lack of skills to utilize devices or facilities (the need for more time and practice to use new software and applications)	[4,7,32,56]
	C26	Instructors' inability to integrate technology or insufficient software skills (which influences the efficiency of the course)	[1,2,4,7,8,28,29,69]

Table 1. *Cont.*

Classification	Code of Challenges	Challenges	Source
Interaction, communication, and satisfaction	C27	Students are struggling to understand online lectures, design juries, and critiques	[8,9,30,32,33,77]
	C28	Lack of peer learning	[2,4,15,22,28,32,69,73,76–78]
	C29	Students are uncomfortable because they cannot view their classmates' progress and projects	[15,30,32,75,77]
	C30	Lack of interaction, communication, and cooperation among students	[4,12,13,15,23,30,32,36,73,77]
	C31	Low interaction and communication issues among students and between students and instructors	[4,6,7,12,13,15,22,23,30,32,36,73,76–78]
	C32	The difficulties in understanding teachers' instructions online	[7–9,13,22,30,32,33,77]
Educational adaptation	C33	Working with 3D and animations without hand sketches or physical models makes expressing design ideas difficult	[4,22,30,54,73]
	C34	Inadequacy of critique frequency and quantity	[7,8,22,33,75,79]
	C35	Student assessment issues	[2,9,29,56,73]
	C36	Lack of immediate access to teachers' help	[30,69,72]
	C37	Concerns about cheating	[56,69,80]
	C38	Increased time spent on lectures and design critiques	[2,7,30,56]
	C39	Students would prefer the new assessment criteria adapted to online education	[22,56,73]
	C40	Adequate and reliable assessment tools are needed due to unsupervised exams, projects, and assignments	[6,56,73]
	C41	It causes stereotypical designs that are far from aesthetic	[9,30,73]
	C42	There will be a biased evaluation as the students' names are visible to the evaluators on screen while evaluating	[9,29,56]
	C43	The focus is on learning the technology rather than on the information taught	[9,15,35]
	C44	Unfamiliarity with quiz/exam formats	[31,56,73]
	C45	Instructors must determine whether the students understand the lesson topics and contents	[31,32,56]
	C46	Instructors cannot agree among themselves on student work or reconciling grades	[2,29,31,73]
	C47	Instructors need help preparing, publishing, and administering online exams	[2,31,56]
	C48	Having students' cameras turned on during online lecture sessions will significantly benefit their learning experience	[21,30,32]
	C49	Working with drawings and 3D models in a digital environment with an adequate hand sketch helps the designs reach the expected maturity level	[4,7,30,73]
	C50	Lack of access to resources	[7,22,29,30,36,73,74,77]
	C51	The absolute need for accessibility to hardware such as tablets and computers	[1,4,6–8,32,73,74,81]
	C52	There must be more privacy and a proper work environment (home and dormitory)	[6,8,15,30,56,77]
	C53	Interruptions of online lessons due to family members or environmental factors	[12,13,15]

4.2. Organizing the Questionnaire

Based on the findings derived from the SLR on OAE, a questionnaire was developed and administered to architecture students in Turkey. The questionnaire consisted of two sections, each tailored to assess relevant variables.

The first section of the questionnaire presented a list of 53 challenges, with respondents asked to rate each challenge on a 5-point Likert scale. This section aimed to capture participants' perceptions of these challenges, with response options ranging from 1 (none) to 5 (very highly). Utilizing a 5-point Likert scale offers a valuable approach to understanding various facets of this field. In this context, structured tools like Likert scales facilitate quantifying and exploring OAE challenges. Moreover, the use of five-point Likert scales assists in evaluating the effectiveness of existing forecasting methodologies and devising optimal strategies within relevant domains [82]. Employing the five-point Likert scale offers a balanced and systematic method for assessing attitudes, perceptions, and probabilities, underscoring its significance as a valuable instrument across diverse disciplines [83].

The second section focused on collecting data on respondents' socio-demographic characteristics, incorporating four questions concerning their year of education, type of university, gender, and age.

4.3. Administrating the Questionnaire and Data Collection

This study focused on architecture students enrolled in Turkish universities as its target demographic. A pilot study was initially conducted by distributing twelve questionnaires to architecture students to assess the clarity of expressions and response times. The questionnaire was refined to its final form based on feedback and recommendations from the pilot study.

The final questionnaire was then emailed to 1108 architecture students using a random sampling method and data collection occurred between 30 April 2022 and 28 July 2022. Of the total questionnaires distributed, 254 were returned. However, 22 of these were excluded due to missing data. Consequently, the final analysis was performed on a dataset of 232 fully completed questionnaires, indicating a response rate of 20.9%. Akintoye [84] suggests that response rates range from 20% to 30%.

The population size for this research is derived from the 2021 statistics provided by the Turkish Chamber of Architects, indicating a total of approximately 40,000 architecture students in Turkey. Employing a random sampling method, a common practice in construction research, ensures that the sample is chosen randomly from the population with a non-zero probability, as Gamil et al. [85] emphasized. This approach effectively generates a sample that accurately reflects the population while mitigating voluntary response bias. Therefore, this method was utilized to select participants for this study. The population's sample size calculation follows a methodology adapted from Gamil et al. [85]. It is detailed as follows: based on the findings derived from the SLR on OAE, a questionnaire was developed and administered to architecture students.

$$SS = \frac{Z^2 \times P(1-P)}{C^2}$$

where

SS = Sample Size;

Z = Z value (1.96 for 95 percent confidence level);

P = percentage picking a choice, expressed as a decimal (0.5 used for sample size needed); and

C = margin of error (9 percent), the maximum estimation error, which can be 9 or 8 percent.

$$SS = \frac{1.96^2 \times 0.5(1-0.5)}{0.09^2} = 118.5 \approx 119 \ (\textit{as the minimum sample size})$$

The formula outlined by Enshassi and Al Swaity [86] is utilized to evaluate the marginal error value. The maximum margin of error for a 95 percent confidence level ≈

$\frac{1.96}{\sqrt{SS}} = \frac{1.96}{119} = 0.19 > 0.09$. The margin is considered acceptable, with a minimum size requirement of 119; hence, the collected 232 data points are also considered acceptable.

4.4. Analyzing the Data

The questionnaire responses were coded and subsequent data analyses, comprising reliability analysis, normalized mean value analysis, and exploratory factor analysis (EFA), were carried out using the Statistical Package for Social Sciences (SPSS) version 29.0. Subsequently, confirmatory factor analysis and structural equation modeling were performed using LISREL version 8.7.

Incorporating the Likert scale necessitates an evaluation of reliability to assess internal consistency among the questions [87]. To ensure the statistical reliability and validity of participants' responses to Likert-scale questions in both the initial and second sections of the questionnaire, Cronbach's Alpha (α) coefficient was utilized. According to Tavakol and Dennick [88], Cronbach's Alpha values range from 0 to 1, with 0.7 considered the minimum acceptable threshold for reliability. Cronbach's Alphas were calculated independently for 53 challenges to establish internal consistency.

To pinpoint the critical challenges among the 53 identified, a normalized mean value (NMV) analysis was conducted for each challenge. According to the calculation, any challenge with an NMV exceeding 0.5 was categorized as a critical challenge (CC), following Equation (1), as outlined in studies by Liao and Teo [89] and Zhao et al. [90].

$$Normalized\ mean\ value \frac{(mean\ of\ challenge - lowest\ mean)}{(highest\ mean - lowest\ mean)} \quad (1)$$

Determining the factor structure was one of the primary objectives of this research. To underscore the significance of the critical challenges (CCs), an exploratory factor analysis (EFA) was conducted on them, employing varimax rotation with an eigenvalue cut-off of 1. EFA can be conceptualized as reducing the number of variables by replacing them with smaller factors that capture the underlying relationships among the variables. Therefore, in its most general form, factor analysis is a technique for identifying concise summary constructs [91]. The primary factors resulting from this analysis, critical factors (CFs), were those exhibiting factor loadings exceeding 0.5, per the criteria outlined by Nunnally and Bernstein [87].

A confirmatory factor analysis (CFA) was performed in the subsequent data analysis phase on the CFs derived from EFA utilizing the LISREL 8.7. software. CFA, which falls within the domain of Structural Equation Modeling (SEM), aims to elucidate the relationships between observed measurements or indicators (such as test items, test scores, and behavioral observation ratings) and latent variables or factors in the measurement models [92].

Finally, LISREL was employed to construct an SEM consisting of two main parts: the hypothetical and structural models. These models evaluate the degree to which various exogenous variables align with latent variables within the framework.

SEM is a valuable reliability measure for assessing the model's suitability concerning the relationships between latent variables and the standardized loadings of the measurement paths. Chin [93] noted that a path coefficient exceeding 0.1 could be deemed sufficient, whereas a value surpassing 0.2 would be considered optimal.

5. Findings

5.1. Reliability of the Questionnaire

The Cronbach's Alpha coefficients (α) for the 53 challenges, which evaluate the reliability of the dataset, were computed to be 0.98, surpassing the minimum threshold of 0.7. This indicates a high level of internal consistency among the responses, implying that the responses provided by participants are highly reliable and consistent.

5.2. Identification of the Critical Challenges

The means and standard deviations for all 53 challenges were computed and presented in Table 2. Normalized mean value analyses identified 24 critical challenges (CCs) out of the 53. C51 had the highest mean value, with a mean of 3.74, earning it a rank of 1, while challenge C5 had the lowest mean value, with a mean of 2.68, ranking it at 53 (Table 2). This ranking analysis revealed that 24 of the 53 challenges had normalized mean values exceeding 0.5, indicating their classification as CCs.

Table 2. Ranking and identification of CCs.

Classification	Code of Challenges	Means and ranking of challenges			Rank
		Mean	Standard Deviation (SD)	Normalized Mean Value (NMV)	
Technical and technological infrastructure	C1	3.10	1.318	0.396	37
	C2	3.23	1.308	0.519 *	23
	C3	3.42	1.4	0.698 *	5
	C4	3.19	1.438	0.481	29
	C5	2.68	1.26	0.000	53
	C6	3.08	1.387	0.377	40
	C7	3.33	1.401	0.613 *	9
	C8	3.09	1.383	0.387	38
	C9	3.25	1.311	0.538 *	19
Health and psychology	C10	3.26	1.396	0.547 *	15
	C11	2.76	1.283	0.075	52
	C12	3.03	1.414	0.330	45
	C13	3.17	1.41	0.462	31
	C14	3.1	1.415	0.396	36
	C15	3.12	1.409	0.415	34
	C16	3.41	1.392	0.689 *	6
	C17	3.15	1.405	0.443	33
	C18	3.16	1.369	0.453	32
	C19	3.24	1.414	0.528 *	22
Interaction, communication, and satisfaction	C20	3.24	1.352	0.528 *	21
	C21	3.11	1.323	0.406	35
	C22	3.46	1.444	0.736 *	4
	C23	3.27	1.374	0.557 *	14
	C24	3.17	1.277	0.462	30
	C25	3.56	1.298	0.830 *	3
	C26	3.6	1.302	0.868 *	2
	C27	3.22	1.31	0.509 *	24
	C28	3.32	1.412	0.604 *	10
	C29	3.06	1.393	0.358	42
	C30	3.37	1.365	0.651 *	7
	C31	3.3	1.372	0.585 *	12
	C32	3.25	1.314	0.538 *	18
Educational adaptation	C33	2.99	1.366	0.292	47
	C34	3.19	1.354	0.481	28
	C35	3.08	1.325	0.377	39
	C36	3.29	1.338	0.575 *	13
	C37	3.19	1.397	0.481	27
	C38	3.25	1.344	0.538 *	17
	C39	2.86	1.248	0.170	49
	C40	3.24	1.326	0.528 *	20
	C41	3.03	1.361	0.330	44
	C42	2.81	1.34	0.123	51
	C43	2.84	1.358	0.151	50
	C44	2.97	1.314	0.274	48
	C45	3.25	1.366	0.538 *	16
	C47	3.01	1.289	0.311	46
	C48	3.06	1.281	0.358	41
	C49	3.19	1.376	0.481	26

Table 2. *Cont.*

Classification	Code of Challenges	Means and ranking of challenges			Rank
		Mean	Standard Deviation (SD)	Normalized Mean Value (NMV)	
Educational adaptation	C46	3.04	1.282	0.340	43
	C50	3.2	1.335	0.491	25
	C51	3.74	1.346	1.000 *	1
	C52	3.30	1.403	0.585 *	11
	C53	3.34	1.45	0.623 *	8

* Denotes CC.

When examining the top five CCs in Table 1, it is noteworthy that the first relates to educational adaptation, while there is a concentration on interaction, communication, and satisfaction. Additionally, by ranking technical and technological infrastructure, one of the primary requirements for OAE is notably last. This ranking and concentration raise important topics about past experiences in OAE that warrant further discussion.

5.3. Determination of Critical Challenge Factors of OAE

Highlighting the factor structure is crucial, as one of the main objectives of this study is to identify critical challenge factors (CCFs). To achieve this goal, exploratory factor analysis (EFA) was conducted using 24 CCs. The EFA utilized the principal component method and Kaiser normalization with varimax rotation was applied in this study. One CC (C40) exhibited factor loadings below 0.5 at the first attempt, which was excluded from the dataset. Consequently, EFA was conducted with 23 CCs (Table 3).

Table 3. Results of EFA and CFA analyses.

Factors	Code of CCs	EFA		CFA	
		Factor Loadings	% of Variance	Standardized Coefficients	
Factor 1	C53	0.762	30.156	0.77	
	C30	0.739		0.86	
	C45	0.731		0.75	
	C31	0.728		0.87	
	C52	0.721		0.77	
	C32	0.707		0.84	
	C28	0.694		0.86	
	C36	0.685		0.74	
	C27	0.660		0.87	
	C23	0.600		0.86	
	C10	0.561		0.80	
	C20	0.564		0.86	
	C19	0.501		0.80	
	C22	0.504		0.81	
Factor 2	C2	0.751	25.519	0.79	
	C9	0.737		0.81	
	C3	0.693		0.81	
	C16	0.636		0.83	
	C7	0.626		0.83	
Factor 3	C38	0.770	16.613	0.60	
	C26	0.697		0.88	
	C51	0.648		0.80	
	C25	0.612		0.83	
Total Variance Explained			72.288	χ^2/df:	2.27
Kaiser-Meyer-Olkin (KMO) Value			0.958	RMSEA:	0.04
Barlett's Test of Sphericity		Approx. Chi-Square:	5538.735	CFI:	0.98
		df:	276	GFI:	0.97
		p:	0.000	AGFI:	0.93

The Kaiser–Meyer–Olkin (KMO) sample adequacy value is 0.958, surpassing the threshold of 0.5, indicating that the dataset is suitable for factor analysis, as Pallant [94] established. Three CCFs with an eigenvalue exceeding one were discerned, collectively explaining 72.288% of the total variance. Below are the interpretations, labels, and codes for each of these CCFs:

- Factor 1: Support, Engagement, and Communication Obstacles in Online Architectural Education (SECO);
- Factor 2: Digital Learning Environment Barriers in Online Architectural Education (DLEB);
- Factor 3: Technological Integration and Accessibility Problems in Online Architectural Education (TIAP).

5.4. Confirmatory Factor Analysis (CFA)

Table 3 illustrates the outcomes of the CFA, revealing that all stressors display loadings exceeding 0.5. Moreover, the model meets the specified goodness-of-fit (GOF) criteria, with a χ^2/df value of 2.27, a Comparative Fit Index (CFI) of 0.98, a Root Mean Square Error of Approximation (RMSEA) of 0.04, and a Goodness-of-Fit Index (GFI) of 0.97. These indices collectively indicate a robust model fit. Based on these assessments of model adequacy, it is noteworthy that the CFA model exhibited a satisfactory fit and can be utilized to evaluate the validity of the measurement scales.

5.5. Establishing the Hypothetical Model

A theoretical model was constructed, wherein each path signifies a hypothetical relationship between a pair of constructs. Subsequently, three hypotheses were formulated (Figure 2).

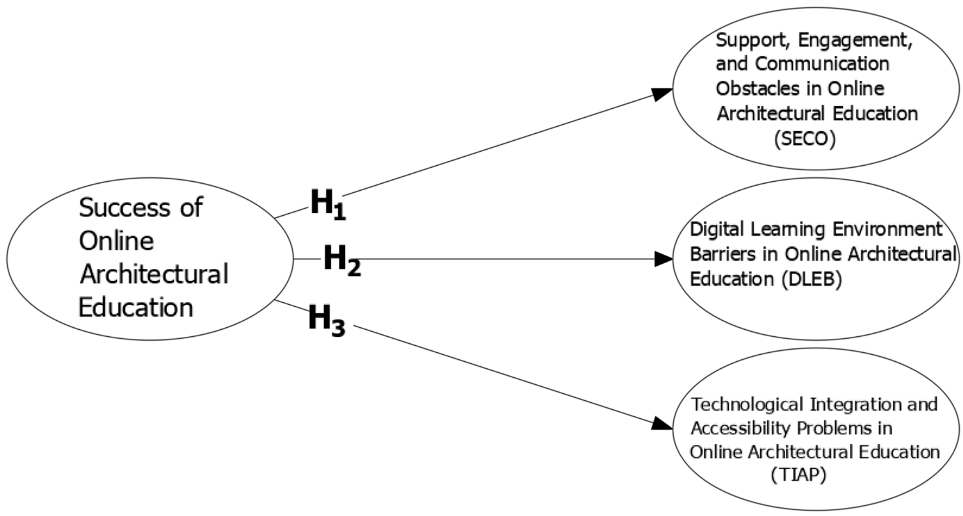

Figure 2. Hypothetical model of the critical factors of OAE.

Considering the three latent factors (SECO, DLEB, and TIAP) as critical factors of OAE, a series of three hypotheses was developed, each corresponding to a distinct path within Figure 2.

H_1: *SECO has a direct effect on online architectural education.*

H_2: *DLEB has a direct effect on online architectural education.*

H_3: *TIAP has a direct effect on online architectural education.*

5.6. Reliability and Validity Testing

Two reliability measures, Cronbach's alpha (α) (CA) and composite reliability (CR), were utilized to evaluate convergent validity and individual item reliability values within the measurement model [92]. In this study, all constructs/latent variables demonstrated CR values surpassing the recommended threshold of 0.70, ranging from 0.966 to 0.880.

Moreover, all CA values exceeded the suggested cut-off of 0.70, ranging from 0.966 to 0.887, as indicated in Table 4.

Table 4. Reliability and AVE results.

Constructs/Latent Variables	CR	Cronbach's Alpha (CA)	AVE
SECO	0.966	0.966	0.82
DLEB	0.907	0.908	0.74
TIAP	0.880	0.887	0.79

Additionally, alongside CA and CR, the Average Variance Extracted (AVE) test was employed to assess internal consistency. Ideally, AVE values should exceed 0.5 [95]. In this study, all AVE values ranged from 0.82 to 0.79, surpassing the required AVE of >0.50, confirming the appropriateness of all constructs, as outlined in Table 4.

5.7. Evaluation of Structural Model

Six separate tests were conducted to validate the inner model [96,97], as detailed in Table 5.

Table 5. Summary statistics of the model.

Fit Index	Suggested Values	Structural Equation Results	Evaluation
χ^2/df	$0 \leq \chi^2/\mathrm{df} \leq 3$	2.31	Good
GFI	$0.95 \leq \mathrm{GFI} \leq 1.00$	0.95	Good
AGFI	$0.95 \leq \mathrm{AGFI} \leq 1.00$	0.91	Good
RMSEA	$0 \leq \mathrm{RMSEA} \leq 0.05$	0.05	Good
CFI	$0.95 \leq \mathrm{CFI} \leq 1.00$	0.97	Good
NFI	$0.95 \leq \mathrm{NFI} \leq 1.00$	0.96	Good

Furthermore, the t-value test, path coefficient, and R^2 values were employed to assess the findings in Table 6.

Table 6. Standardized coefficient estimates (*p*-value) of the final structural equation model.

Hypothetical Paths and Expected Influences	Path Coefficient [a]	*t*-Value (1-Tail)	Interpretation	R^2
H1: SECO→OAE	−0.96	13.17	Supported	0.92
H2: DLEB→OAE	−0.95	13.29	Supported	0.90
H3: TIAP→OAE	−0.84	11.76	Supported	0.69

Note: [a] All standardized path coefficient estimates are expected to be significant at $p < 0.01$.

Each hypothesis exceeds the critical one-tailed t-value of 2.58 at a significance level of 0.01. The SEM analysis indicates that all hypotheses within the conceptual model received support, as shown in Table 6 and Figure 3.

All hypothesis tests rejected null hypotheses with a 99.0% confidence level and t-values exceeding 2.58, as depicted in Figure 3 and Table 6. Table 6 and Figure 3 illustrate that SECO (0.96), DLEB (0.95), and TIAP (0.84) have the most substantial impact on OAE.

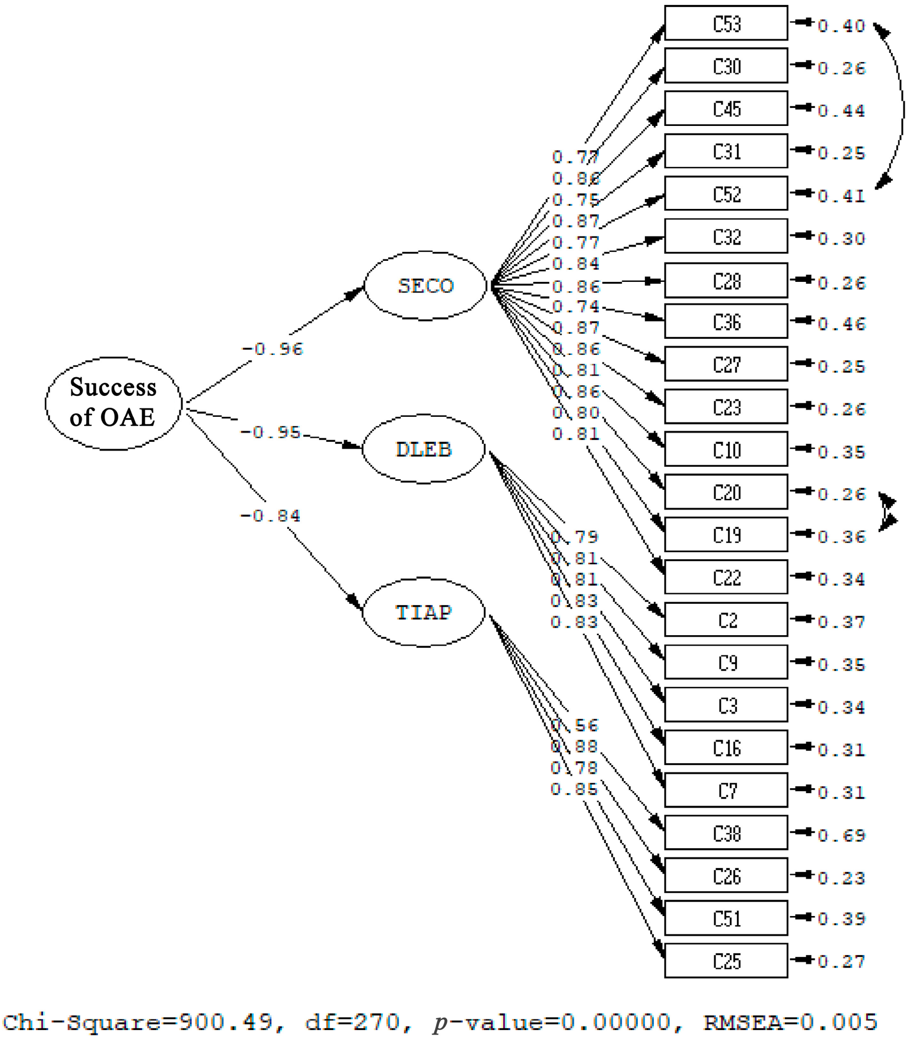

Figure 3. Final SEM of critical factors of OAE.

6. Discussion

This research identified and ranked CCs and then developed and validated a model to examine and assess the CCFs influencing the success of online architectural education. This section emphasizes the top challenges ranked by NMV and three latent factors identified through EFA, CFA, and SEM that exert the most significant influence on online architectural education.

6.1. Examining the Criticality of Top Challenges

Online education's full potential lies in its accessibility to everyone, removing barriers and fostering an inclusive learning environment. However, a significant challenge to accessibility in online education is the insufficient educational technology infrastructure [98,99]. This is particularly evident in disciplines with unique demands, such as online architectural education. Moreover, this study identified the lack of accessibility to hardware such as tablets and computers as the primary challenge in online architectural education as the most critical challenge. Without such equipment, the efficacy of this mode of learning becomes questionable. Furthermore, the accessibility of appropriate educational technology (EdTech) can pose challenges for educational institutions, particularly those with limited financial resources. The expense of assistive technologies, such as specialized hardware, can be a significant obstacle, especially for those from low-income backgrounds. In addressing these challenges, governments play a crucial role in providing adequate funding and resources to enhance accessibility in online education. Additionally, governments and other education authorities can provide support beyond legal regulations by allocating funds to improve accessibility in educational institutions. This support may include grants for acquiring assistive hardware and funding for research into innovative accessible teaching devices. Such assistance is vital for architectural schools, particularly those with limited budgets, to meet accessibility standards and ensure that all students have equitable access to online learning opportunities. Nevertheless, this study's findings clearly indicate that education deficiencies are primarily attributed to economic factors in developing countries with ongoing economic development.

Among these challenges, instructors' inability to integrate technology or insufficient software skills is the second most significant. Shulman [100] introduced the concept of 'Technological Pedagogical Content Knowledge' (TPACK) for instructors, referring to their ability to effectively integrate technology into teaching methods while considering content and pedagogy [101]. Research suggests that instructors with developed TPACK skills can use various technological tools to present information and assess students' comprehension [102]. Moreover, instructors with adequate TPACK skills demonstrate a deep understanding of student challenges and can effectively address them. Instructors must comprehend students' cognitive levels and use suitable teaching strategies, especially in the digital environment, to enhance learning outcomes.

Additionally, instructors are expected to become proficient in using technology apps and platforms for grading, record-keeping, and implementing strategies to improve students' literacy skills and demonstrate learning [101]. Studies indicate that instructors are comfortable integrating technology, creating a more compelling online education environment [103,104]. In this context, enhancing instructors' TPACK skills is crucial for improving the quality of online architectural education [2,105].

The third-ranked critical challenge is the lack of skills to effectively utilize devices or facilities and the need for additional time and practice to learn how to use new software and applications. It is undeniable that architecture students dedicate themselves to enhancing their digital competencies, leveraging digital models and cutting-edge augmented technology to refine the architectural design process. Nevertheless, in past decades, educational institutions often hesitated to implement online learning in architecture courses due to the prevalent studio-based teaching tradition emphasizing in-person interaction. Consequently, while many theoretical disciplines may seamlessly transition to online systems, architectural education encounters more significant challenges [106,107]. In this context, the sudden shift to online learning due to university closures revealed numerous conceptual, educational, and technical gaps. Faculty, including those in architectural education, had to adapt to online teaching with minimal training quickly. At the same time, students faced disruptions and the challenge of acquiring new technological skills alongside their studies [108,109]. Given the COVID-19 experience, it is evident that these challenges stem from the need for digital skills and experiences among architectural students before the pandemic. However, with the onset of the COVID-19 pandemic, technology has become indispensable in architectural education for online courses. This shift has necessitated students' adaptation to the new education landscape and mastery of digital skills. Proficiency in digital skills enables students to engage in self-directed learning effectively, identifying learning needs, utilizing online resources, applying information, and evaluating results, thereby enhancing work efficiency and productivity [110].

Moreover, digital skills foster greater engagement and creativity in online architectural design courses. By prioritizing digital skills, architectural students can collaborate effectively in classrooms and at a distance, improving teamwork and efficiency. It is essential to ensure that architecture students are prepared for potential disruptions in the post-pandemic era, drawing from the experiences gained during the pandemic.

On the other hand, the shift to online architectural education has separated students geographically from their campus environment and peers [34]. This physical distance can lead to disconnection and isolation among students, particularly affecting interpersonal relations and diminishing the sense of community [111]. However, participants can establish a sense of community when they feel they have contributed sufficiently to forming personal relationships in the online platform [112]—previous research indicates that higher levels of learning occur among students who engage with each other [32]. Moreover, a sense of community can be fostered through activities designed to bring students together [113]. Therefore, universities can effectively move social facilities to the digital environment by enhancing their expertise in online education and providing highly interactive activities. This approach will increase architecture students' interest in online education and strengthen their sense of belonging to the university culture.

The last of the top five critical challenges is the need for a fast and stable internet connection related to the technical technological infrastructure. Unsurprisingly, access to Internet services emerged as a significant challenge for students in many developing countries following the transition to online education [8,11,30]. However, students' ability to effectively participate in distance courses depends on appropriate internet accessibility, which is essential for online education [15,21]. This was particularly evident in developing countries, such as Turkey, where architecture students faced specific issues related to internet accessibility [17,114]. Moreover, while universities in some regions could provide additional internet services for distance learning, this was only feasible for some institutions in areas like East Africa [115]. The sudden unavailability of services previously provided by universities on campus exacerbated this issue. Therefore, addressing the inequality of internet access is crucial for fostering a more inclusive online architectural education environment.

Additionally, the information and communication technologies (ICT) in many university campuses across developing countries need to be more robust, with unreliable internet connectivity and insufficient bandwidth to support large-scale synchronous activities or accommodate the transfer of large files [99]. Therefore, there is an urgent need to upgrade university systems to ensure they meet educational requirements. In this way, added value and progress can be achieved in online education on a global scale.

6.2. Evaluation of Critical Factors

SEM revealed CCFs in this study and confirmed the research hypotheses. According to Hair et al. [96], path coefficient values close to 1 indicate a strong association, while values near 0 suggest a weak relationship. Despite variations in the path coefficient values among the hypotheses, all values in this study exceed 0.8. Consequently, the CCFs with path coefficient values between 1 and 0.8 are deemed the most significant. Therefore, all components in the three-factor model of this study were identified as the most critical factors.

6.2.1. Support, Engagement, and Communication Obstacles in Online Architectural Education (SECO)

SECO is the most influential critical challenge factor of OAE, with a path coefficient of 0.96. Interactivity and communication are crucial aspects of architectural education as primary unifying elements among other components essential to the discipline. Previous studies have also underscored the negative impact of online education stemming from the absence of social interaction [4,30,32,73,77]. This absence not only results in the social isolation of students but also impedes their communication and collaboration with peers and instructors [116]. In this context, many researchers have examined the importance of these variables in architectural education. Margalina et al. [117] stated that online education quality depends on interaction quality. Bhandari et al. [11] argued that lack of interaction was a valid and significant risk. In particular, Tandon et al. [9] revealed a strong relationship between students' behavioral intentions and the absence of interaction, which they identified as a significant barrier to online architectural education. In this context, indirect communication has created an interaction barrier, posing a significant risk for architecture students. This barrier resulted in a loss of human connection with peers and instructors, leading to feelings of insecurity [118]. Therefore, many researchers have developed various approaches to enhance online architectural education based on interaction, which fosters social learning. The "BEL+T DIAgram" framework, which encompasses three primary tasks of teaching, namely delivering content, facilitating interaction among architectural students, peers, and staff, and adequate assessment [35,119], along with the "IDEA" (Interact, Define-Draw, Engage, and Assess, respectively) methodology by Travis [33], serves as models of this perspective. While this factor has been recognized as one of the risks in online architectural education, the former research has yet to detect its size effect. SECO has emerged as the most critical challenge for OAE in this study, specifically for Turkey. This result may be attributed to the underdevelopment of online education in Turkey, even in fundamental educational branches, not to mention architectural education [17].

Moreover, psychosocial concerns in online architectural education are still important issues that must be addressed [2,6,7,22,32]. If this is ensured, it will also contribute to the psychosocial health of students. Therefore, despite the transition to online platforms, architectural education should remain highly interactive, incorporating active learning exercises and utilizing diverse online tools in the future. Since this conclusion applies globally and is essential for online architectural education, this principle can be generalized to other countries where similar results can be obtained and this factor should be understood and prioritized in Turkey and other developing countries.

6.2.2. Digital Learning Environment Barriers in Online Architectural Education (DLEB)

The second most influential critical challenge factor is DLEB, with a path coefficient of 0.95, nearly the same as SECO regarding its impact. Online architectural education succeeds with an adequate technological infrastructure [4]. In this regard, technology and technical infrastructure are crucial aspects that underpin this form of education. However, the pandemic-driven crisis has deprived education stakeholders of the opportunity to prepare for online education transformation [17]. Hence, instructors commenced online teaching, needing more technical facilities suitable for online education [53]. Many scholars have identified this absence as one of the most significant challenges encountered in online architectural education [2,11,15,21,73]. In particular, Alnusairat et al. [7] revealed that the critical challenges of online architectural education include technical issues and insufficient expertise in online teaching. Brzezicki [36] argued that the challenges primarily revolve around technical issues. As Nubani et al. [32] noted, architectural students have faced challenges in quickly adjusting their learning behaviors due to their lack of familiarity with new approaches. Therefore, when addressing technical constraints in online architectural education, it is imperative to acknowledge the importance of experience in navigating these domains.

6.2.3. Technological Integration and Accessibility Problems in Online Architectural Education (TIAP)

The third most influential critical challenge factor, TIAP, is nearly as significant as the first two, with a path coefficient of 0.84. While it removes geographic boundaries, online education provides an opportunity to increase diversity [69] and opens the classroom walls, making lifelong learning possible [2,28]. Indeed, as Güler [58] and Yu et al. [34] mentioned, one of the most significant opportunities in digitalizing architectural education is accessibility for all. Therefore, successful adaptation to online educational practices relies on the availability of up-to-date technological tools and services that are accessible and relevant for all individuals [6,21]. However, this pertains not only to access to devices, resources, and software but also to the ability of individuals to connect regardless of time and location.

Additionally, the current study has revealed a direct correlation between accessibility in online architectural education and students' self-efficacy. Students can manage and guide themselves effectively when they can access and utilize the necessary facilities. This fosters autonomy in their learning process and facilitates self-realization. Furthermore, an approach proposed by Rook and Hooper [120] suggests that incorporating and ensuring computer technologies in architectural education empowers students to control their learning process.

Previous studies [2,14,23,29] have underscored the significant role of innovative methods in eliminating various barriers associated with the success of online architectural education. Specifically, the current study presents a three-factor core model. The conceptual models in this regard include those developed for Egypt [30] and India [9,11]. A comparative study on architectural design communication with Spain by Akçay Kavakoğlu et al. [4] is also available for the Turkish context. However, to our knowledge, no study explicitly examines and models the critical factors of online architectural education. Therefore, the current study holds particular significance within online architectural education.

7. Conclusions

The COVID-19 pandemic has brought about significant changes in architectural education, adversely affecting all stakeholders involved in the educational process. Educational institutions worldwide encountered challenges transitioning to online architectural education during the pandemic. This situation has become more problematic, particularly in developing countries, for various reasons, including economic, cultural, and sociological factors. Therefore, the present study explores the challenges of transitioning from face-to-face to online modes and examines how architectural students experienced this shift. Using SEM, it identifies CCFs in online architectural education among Turkish architecture students, serving as a model for developing countries. The present study provides vital insights for successfully adopting online architectural education, highlighting the critical factors hindering its adoption. To the best of our knowledge, this issue has yet to be investigated using this approach in architectural education.

A systematic literature review revealed 53 challenges hindering the success of OAE. A questionnaire containing 53 challenges was devised and distributed among architecture students in Turkey. Statistical analysis was performed on 232 completed questionnaire forms, identifying 24 of the 53 challenges considered CCs. While this does not imply that the other 29 criteria lack importance in the success of online architectural education, their impacts may not be sufficient to warrant classification as critical within the scope of this research. The EFA and CFA conducted in this study revealed three CCFs influencing the success of online architectural education. Subsequently, using SEM, these CCFs were modeled and their effect sizes were determined.

SEM revealed that support, engagement, and communication obstacles in online architectural education (SECO), digital learning environment barriers in online architectural education (DLEB), and technological integration and accessibility problems in online architectural education (TIAP) were the critical success factors for online architectural education, with path coefficients of 0.96, 0.95, and 0.84, respectively.

This study is distinguished by its examination and specification of the CCFs hindering the success of online architectural education in Turkey, which holds significance for similar practice-based educational pedagogies. Moreover, this study is among the few research endeavors that have constructed a quantified model to illustrate and gauge the effect size of critical factors in online architectural education. Such findings will prove invaluable for curriculum developers and all education stakeholders in Turkey, aiding in formulating suitable frameworks for implementing online architectural education within Turkish higher education. Furthermore, these frameworks could be generalized to other educational disciplines and developing countries, as asserted from the outset. Lastly, the current study adds to the existing literature and provides significant implications for architectural education, as outlined below.

7.1. Enhancing Minds: Practical Implications for the Future

The present study used the proposed model to determine the CCFs for online architectural education. Its findings provide valuable insights for all stakeholders in higher education and have generated recommendations to enhance the success of architecture students in the online education environment.

This study presents a framework to facilitate the effective implementation of online architectural education. The current study demonstrates three CCFs of online architectural education. Accordingly, "Support, Engagement, and Communication Obstacles in Online Architectural Education (SECO)" is the most influential critical challenge for online architectural education. In this context, several practical recommendations can be proposed concerning the impacts of this factor:

- Educational authorities should prioritize enhancing students' interaction and communication with peers and faculty members. This will also reinforce a sense of belonging;
- Enriching peer learning will be beneficial for all students. Therefore, educational institutions should adopt approaches that provide opportunities for socialization, collaborative learning, and group engagement;
- It would also be beneficial to ensure that cameras used in online courses remain activated to promote interaction and emotional connection;
- Educational authorities should facilitate access to assistance from faculty members. Providing direct access opportunities can be crucial for students;
- Online courses and design juries should be simplified for better understanding, utilizing concise and adequate concepts. Additionally, instructors should provide more explicit and precise instructions and expectations for students, enhancing the educational process;
- Making lectures and presentations engaging contributes significantly to the online educational process by increasing students' interest and attention in the courses;
- Educational institutions should strive to recreate a virtual campus atmosphere online. This can be achieved by reflecting university culture in the virtual environment through digital tools and interactive platforms, which will help reinforce the bond between students and the university;
- Students should have access to appropriate study environments. Additionally, steps can be taken to minimize interruptions during online class sessions. Raising awareness among family members and other stakeholders about this matter is essential;

The next most critical factor for the success of OAE is "Digital Learning Environment Barriers in Online Architectural Education (DLEB)", which is mainly concentrated in a specific domain;

- Prioritizing technology-oriented education will enhance the success of online education systems in architectural education;
- Given users' lack of software experience and diversity, opting for more user-friendly applications would be advantageous;
- It would be favorable to provide fast, affordable, secure, and easily accessible Internet service for all education stakeholders;
- Students and instructors should receive technical support and guidance on using technology and tools in online architectural education;
- Students' time spent awaiting instructor feedback should be minimized, accompanied by increased frequency and volume of feedback. Additionally, students should be encouraged to ask questions and seek assistance when required. Establishing a feedback loop between instructors and students, encompassing a range of topics, can also prove advantageous. Continuous improvement cycles, achieved through ongoing evaluations and enhancements, will enrich the learning experience;

The third most important factor is "Technological Integration and Accessibility Problems in Online Architectural Education (TIAP)". To address the challenges of online architectural education, several measures can be implemented based on this factor;

- Licensed software, platforms, and hardware, such as tablets and computers, should be provided;
- Access to mobile devices should be increased and alternative devices should be permitted;

- Students should be provided with adequate time and preparation to familiarize themselves with new software and applications. Encouraging them to gain practical experience in using these tools would be beneficial;
- Offering training sessions for instructors on utilizing technology and online course tools would prove advantageous for online architectural education. Indeed, developing instructors' ability to integrate technology, their pedagogical content knowledge, and their proficiency in online teaching methods are crucial for the success of online architectural education;
- Providing online access to resources like libraries and archives would greatly benefit students;
- Utilizing digital resources for course materials can be advantageous. Opting for digital copies when selecting resources and materials would be beneficial;
- The proposed conceptual framework, which identifies the CCFs, will assist those implementing online architectural education in achieving success. With these distinctive features, it stands out significantly within its relevant context. To further enhance its success, all education stakeholders should adapt themselves and the curriculum accordingly. This adoption is crucial, particularly considering the disparities between developed and developing countries. By comprehending these differences, educational institutions can craft course materials and training packages suited to the challenges and opportunities encountered in developing nations. Overall, the variations in architectural education between developed and developing countries underscore the necessity for a customized approach that considers the specific contexts, challenges, and priorities of each setting;
- Higher education institutions transitioning to online learning will strategically redesign their curricula, enhancing flexibility and capacity within the broader digitized educational environment. This adaptation will better equip them to navigate the challenges of an increasingly online world. Indeed, educational authorities are increasingly embracing this new approach. Therefore, the implications of this study will extend beyond borders, particularly as institutions worldwide consider the transition to online formats for architectural education.

7.2. Limitations of the Study and Guidelines for Future Research

The results of this study offer guidance for all stakeholders in architectural education who seek to transition to distance learning while effectively investigating architectural students' experiences. While considerable efforts have been dedicated to contributing significantly to the existing literature in this study, it has some limitations. Firstly, the focus is primarily on students' experiences, which are central to the educational process. Future studies can aim to enrich this study by incorporating the perspectives of architecture faculty members regarding their teaching experiences.

Second, in the academic cycle, where there is a learner, there is invariably an instructor. This study delved into the learner aspect of this cycle. Future studies can complement this by examining the instructors' role, thus completing the cycle.

Furthermore, there were no architecture students with special needs (e.g., visual and hearing impairments) in the sample group of this study. Therefore, the expectations and evaluations of architecture students with special needs are another limitation of this study. Scholars may concentrate on students with special needs or include them in their sample group.

While this study has comprehensively examined online architectural education, focusing on all critical challenge factors contributing to its success, future research can delve into more specific aspects and uncover latent dimensions influencing its effectiveness. For instance, scholars researching online education have noted a tendency to prioritize learning technology over educational pedagogy.

Moreover, although efforts have been made to integrate information and communication technology (ICT) into pedagogy, persistent challenges persist. These unresolved issues warrant further investigation, particularly within online architectural education, to identify hidden factors hindering successful adaptation.

Lastly, this study utilized a representative sample from a single country. Subsequent research could improve sample diversity and investigate various demographic perspectives within online architectural education.

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