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Scientific articles

Diagnóstico de incorporación de herramientas digitales en la Educación Arquitectónica

Diagnosis of incorporation of digital tools in Architectural Education

Diagnóstico da incorporação de ferramentas digitais na Educação em Arquitetura

Luz Angélica Mondragón del Angel
Universidad Autónoma de Querétaro, México
luz.mondragon@uaq.edu.mx
https://orcid.org/0000-0001-5997-182X

Sandra Luz Canchola Magdaleno
Universidad Autónoma de Querétaro, México
sandra.canchola@uaq.mx
https://orcid.org/0000-0002-7497-281X

Resumen

La Educación Superior en Arquitectura enfrenta desafíos debido a la constante evolución de las herramientas digitales en esta área. Se examinó la incorporación de herramientas digitales en la Licenciatura en Arquitectura de la Universidad Autónoma de Querétaro, México, para identificar las condiciones que permitan la construcción de un marco pedagógico para una incorporación oportuna y eficiente. Se utilizó un método mixto bajo el Diseño de Triangulación Concurrente. Los análisis fueron cuantitativo, exploratorio, descriptivo, transversal, y cualitativo, de acuerdo con la Teoría Fundamentada. Los resultados mostraron que las redes sociales son importantes medios de aprendizaje y actualización; y el aprendizaje autodidacta prevalece entre los estudiantes. La manera en que los estudiantes incorporan herramientas digitales depende del proceso de diseño. Se observó una preferencia por las herramientas digitales sobre las técnicas tradicionales, y se recomendó una integración

gradual. Se requiere de la percepción del profesorado para desarrollar un modelo pedagógico contextualizado integral.

Palabras clave: arquitectura, diseño, estudiantes, incorporación, software.

Abstract

Higher Education in Architecture faces challenges due to the constant evolution of digital tools in this area. The incorporation of digital tools in the Bachelor of Architecture program at the Autonomous University of Queretaro, Mexico, was examined to identify conditions that would allow the construction of a pedagogical framework for timely and efficient incorporation. A mixed-method approach was used under the Concurrent Triangulation Design. The analyses included a quantitative exploratory descriptive cross-sectional study and a qualitative study based on Grounded Theory. The results showed that social networks are important means of learning and updating knowledge, and self-directed learning prevails among students. The way students incorporate digital tools depends on the design process. A preference for digital tools over traditional techniques was observed, and a gradual integration was recommended. A teachers' perception is required to develop a contextualized pedagogical model in a comprehensive manner.

Keywords: architecture, design, students, incorporation, software.

Resumo

O Ensino Superior em Arquitetura enfrenta desafios devido à constante evolução das ferramentas digitais nesta área. A incorporação de ferramentas digitais no Bacharelado em Arquitetura da Universidade Autônoma de Querétaro, México, foi examinada para identificar as condições que permitem a construção de um quadro pedagógico para uma incorporação oportuna e eficiente. Um método misto foi utilizado no Projeto de Triangulação Simultânea. As análises foram quantitativas, exploratórias, descritivas, transversais e qualitativas, de acordo com a Teoria Fundamentada nos Dados. Os resultados mostraram que as redes sociais são importantes meios de aprendizagem e atualização; e a aprendizagem individualizada prevalece entre os alunos. A forma como os alunos incorporam ferramentas digitais depende do processo de design. Observou-se uma preferência por ferramentas digitais em detrimento de técnicas tradicionais e recomendou-se uma integração gradual. A percepção do corpo docente é necessária para desenvolver um modelo pedagógico abrangente e contextualizado.

Palavras-chave: arquitetura, design, estudantes, incorporação, software.

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Introduction

The integration of technologies in the educational field has been a frequent topic of study, even more so with recent technological innovations that impact very specific sectors of education, such as Higher Education in Architecture, which has historically had a considerable evolution and adaptation in terms of the incorporation of digital tools that support design and graphic communication.

In the case of Building Information Modeling (BIM), developing skills in this area can enhance students' problem-solving capabilities, better preparing them to meet design challenges (Hossain and Bin, 2022). Also, integrating 3D printing technology into the teaching process is a means to improve students' perception (Boumaraf and İnceoğlu, 2020).

It has been observed that technologies such as virtual reality (VR) can be an important tool for enhancing learning (Radianti *et al* ., 2020). Furthermore, VR allows the generation of new teaching-learning methodologies (Bashabsheh *et al*., 2019; Fromm *et al*., 2021; Hajirasouli and Banihashemi, 2022) and is considered a positive tool for communicating the architectural project (Redyantanu and Asri, 2021). Like augmented reality (AR), it can lead to better learning outcomes, taking into account mental rotation skills (Krüger *et al*., 2022).

However, the introduction of these technologies into architectural education presents significant challenges. Visualization software, which used to be a tool for teaching skills, is now a target for both teachers and students, and its widespread use has negatively affected their imagination and creativity (Mahmoud, 2020). Furthermore, students' creativity can be affected by certain features of some technologies, for example, representation systems such as BIM, which relies on physical relationships and strict construction rules, which can hinder creativity and innovation in architectural design due to its rigidity (Castelo-Branco *et al*., 2022).

The problem with implementing these digital tools is the potential dependence of students on the use of software, which can limit their ability to think creatively and flexibly. This is extremely important in the context of architecture, where the ability to innovate and create is critical. The focus on these tools could result in training that prioritizes efficiency and precision at the expense of creativity.

While studies have been conducted on the integration of digital technologies in architectural education worldwide, there is a lack of research that addresses how these tools are

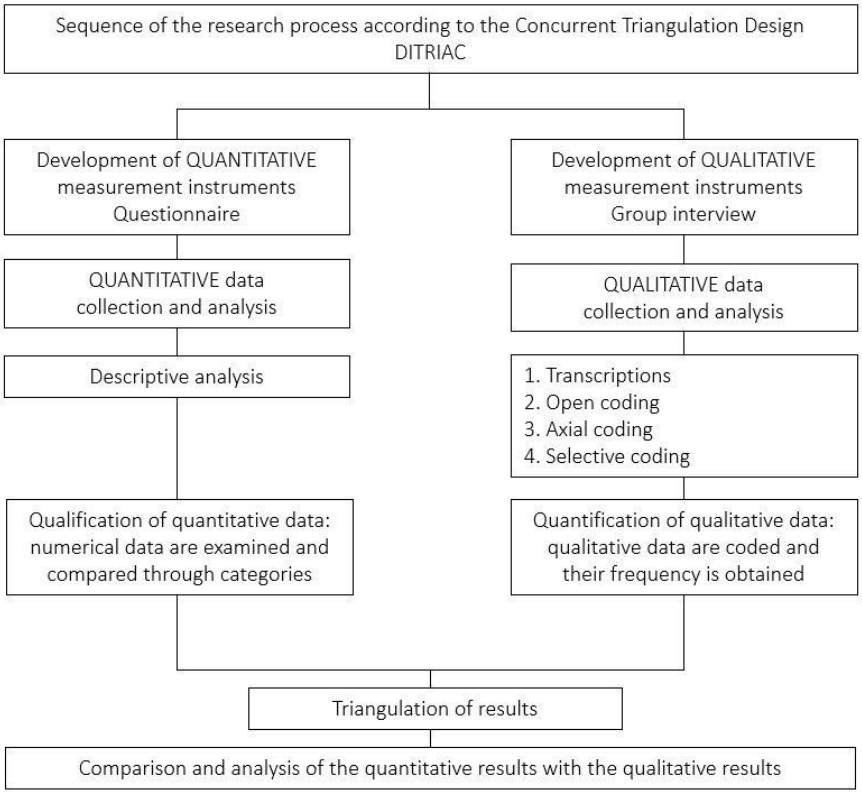
used and integrated into specific curricula in Mexico. Thus, understanding is limited regarding how these technologies impact the teaching-learning process in local contexts, and whether the pedagogical methodologies used are the most appropriate to take advantage of the benefits of these technologies. Without a clear vision of how these technologies affect both the teaching process and the learning outcomes, there is a risk of technological incorporation that is not aligned with the specific needs and contexts of students and teachers.

In this regard, there is a need to analyze the current state of the incorporation of digital tools focused on architecture, in particular graphic representation technologies, in a specific educational context to understand in depth how to integrate them from a pedagogical approach, for the benefit of the teaching-learning process of architectural education. Thus, the research took place in the curriculum of the Bachelor of Architecture at the Autonomous University of Querétaro (UAQ), based on the following research question: What is the current state of the incorporation of digital tools in the graphic representation subjects of the Bachelor of Architecture at the UAQ? The main objective was to analyze and understand how digital tools are used in subjects related to graphic representation within the curriculum of the Bachelor of Architecture at the UAQ. By identifying the strengths and limitations of the current approach, more effective educational interventions can be designed that promote technical competence, creativity, and innovation.

Materials and methods

In the field of architectural education, practices and experiences are very diverse, so the use of mixed methods allows obtaining a detailed and precise overview. The research design for mixed methods called Concurrent Triangulation Design (DITRIAC) was used, in which the collection and analysis of quantitative and qualitative data is carried out simultaneously. The analyses are carried out separately and at the end a cross-validation between quantitative and qualitative data is performed (Fig. 1). The results are compared and discussed in depth in the interpretation stage (Hernández *et al*., 2014) .

Figure 1. Research process



Source: Own elaboration based on Hernández *et al* (2014)

The context of the study was the curriculum of the Bachelor's Degree in Architecture at the UAQ, specifically the teaching-learning processes linked to graphic representation technologies. The curriculum was structured according to the analysis of the needs of the region at the time, as well as the background of the degree since its inception. The curriculum of the Bachelor's Degree in Architecture is divided into seven areas of knowledge: Design and projects, Technology, Theory and History, Communication, Urban environment, Management and Comprehensive training.

The subjects of the Communication axis seek for students to develop competence in graphic, written and oral language in architecture to communicate projects with precision and with technical terminology, aspects that correspond to the guidelines established by the National Accreditation Agency of Architecture Programs and Disciplines of Habitable Space AC (ANPADEH, 2024), which is the accrediting body of academic programs of Higher Education in Architecture in Mexico.

The subjects in this area that were included in the research were Descriptive Geometry, Technical Drawing, Graphic Expression, Model Workshop and Digital Tools for Architecture I. These are taught from the first to the third semester, out of ten that make up the curriculum.

The subject of digital tools is serialized in the third, fourth and fifth semesters. The rest of the subjects in this area are project dissemination, research seminar and graduation seminar.

The population under study were students of the Bachelor of Architecture at the Autonomous University of Querétaro enrolled in the subjects of the disciplinary axis of Communication: Descriptive Geometry, Technical Drawing, Graphic Expression, Model Workshop, Digital Tools for Architecture I from the first to third semester of the period 2023-2.

The quantitative and qualitative sampling frame was determined according to the following factors: the capacity for collection and analysis, and the understanding and nature of the phenomenon. The minimum sample sizes for quantitative and qualitative studies were considered according to the types of descriptive cross-sectional study and grounded theory with a minimum of 30 cases as the suggested minimum sample size for the quantitative branch, and 20 to 30 cases for the qualitative branch (Hernández *et al*., 2014).

Thus, the sampling to be used in the mixed method for both approaches was non-probabilistic convenience sampling, in which 30 cases were selected, six students enrolled in each of the subjects included in the study, who were voluntary participants who responded to the open invitation made in person through a talk in their classroom. The sample used in the quantitative study and in the qualitative study is the same, that is, it is a single sample that participates in both approaches.

Quantitative research

Within the scope of quantitative research, a cross-sectional, descriptive and exploratory study was developed, which was focused on describing the characteristics of the phenomenon under study. A questionnaire of 25 questions was designed, with 13 closed multiple choice questions, six multi-response questions and six open questions. The reliability of the instrument was verified qualitatively by three experts, who independently evaluated the relevance, pertinence and congruence of the questions with the variables to be measured, as well as the clarity and bias in the wording. The questions that obtained full approval by the experts were included in the questionnaire, those questions that were completely rejected were eliminated, while questions that were partially approved were reviewed and reformulated to be validated again. A pilot test was carried out and adjustments were made. The questionnaires were applied from October to November 2023 in physical form in printed format.

Qualitative research

For qualitative research, the method involved immersing oneself in the data collected and searching for classifications, codifications and comparisons according to the Grounded Theory approach (Hernández *et al*., 2014). This analysis seeks to explain and interpret reality. A semi-structured group interview script was designed for students. The elaboration and application followed the stages of research with interviews, starting with the thematic organization, design and execution of the interview. Later, its transcription, analysis, verification and writing of the report (Kvale, 2007).

The analysis began with open coding, which consists of dividing the data into words, phrases and sentences to identify categories and their properties (Hernández *et al*., 2014). That is, descriptors, known as codes, were assigned to the information obtained in the interviews. The codes and categories were classified and compared until saturation was reached, then axial coding continued, and finally selective coding was performed, which led to the central category.

The core category is the code that provides explanation and coherence to all the data and their interrelations, "it explains the greatest variability in the pattern of social behavior under study" (Carrero *et al*., 2012, p. 35). The core category was determined based on the criteria: relationship with other categories, frequency in the data, inclusion and link to others, clarity of its implications, and finally contribution and application (Hernández *et al*., 2014).

Results of quantitative research

The digital tools used by students in their classes are mostly educational tools (33%) and communication and interaction tools (31%), and to a lesser extent design software (23%) and data analysis tools (10%). Only 2% of students said they do not use any digital tools in their classes.

Most students learned to use these digital tools primarily through self-taught learning (77%) and the rest learned through formal training they received at school.

In this regard, 67% of students mentioned not having faced any challenges when using digital tools in their classes, only 23% said yes and 10% said maybe. The way they have overcome the challenges they have faced with the use of digital tools has been by asking classmates or teachers, as well as searching for information on the Internet, in YouTube tutorials or online courses. They mentioned not having a computer as a challenge, and to solve

it they had to buy a new one. Some considered that another challenge is that there is not enough time in class to resolve doubts.

Students preferred digital graphic representation (43%). Among the reasons for their choice, they indicated that digital graphic representation provides greater accuracy in the strokes, and they consider it to be faster and easier. Secondly, they preferred both digital graphic representation and manual graphic representation (33%), because the use of both representation techniques allows them to complement each other. And finally, they preferred manual graphic representation (23%) mainly because of the freedom it gives them to draw by hand and because they do not yet have any notions of digital drawing.

Drawing up plans (31%), making sketches (29%), making renders (16%) and 3D models (16%) are the types of work in which students most frequently use digital graphic representation tools. In this sense, 83% of students considered that digital tools have improved the quality and precision of their work, 13% believed that perhaps they had, and the rest indicated that they had not.

All students stated that mastery of digital tools is essential for a successful career as an architect. Most students (90%) mentioned that mastery of these tools requires significant practice time and 10% believed that it might.

The digital tools for architecture that students indicated as their favorites to use in their classes were: 1. AutoCAD, 2. Revit and 3. Sketchup. They prefer them because they are the most common, because they are practical, because they are the ones they know and find their interface easy to manipulate and learn. They consider them to be interactive and, in addition, they have not had contact with other tools.

As their favorite digital device to use in their classes, students preferred the laptop (93%) because of its practicality and ease of transport, because it is common, because it is the one they have and because they can install various software due to its storage capacity, in addition to the fact that the size of the screen allows them to better view the work to be done.

According to the results, 93% of the students said they know what VR is, 50% said the same for AR and only 20% said they know what BIM is. In this regard, 93% of the students said they have not used or are not users of any specific VR, AR or BIM software.

Most students (87%) said they should learn to use a VR, AR or BIM application, and only 13% said they might. Likewise, 63% of students considered that in the medium term they will be users of these three technologies, 33% said they might and 3% said they wouldn't. Most students (90%) would like to include VR, AR or BIM to a greater extent in their university

program. In this regard, 43% of students indicated that the bachelor's degree program does promote the use of both digital and manual representation techniques, 33% said they might and 23% said they wouldn't.

Regarding students' perception of their current professional development, two main options were found: the first was that students do not receive training or ongoing education to keep their skills in digital tools up to date (40%), and the second was that they do receive it on their own (37%). Only 23% stated that they receive training from their educational institution.

Students commented that the use of digital tools is a necessity in the course, as it offers advantages in terms of time optimization and efficiency. They find it important that they are taught how to use digital graphical representation tools from the first semester, as an introduction so that, later, they have a more solid notion of their use, since they mentioned that learning at the pace of a digital tool is difficult for them, when they are not familiar with it. They also propose that the integration be alongside or in combination with traditional graphical representation methods to improve creativity and the generation of ideas.

Although the students considered the way the curriculum is structured to be adequate, they would like the program to contain more virtual VR materials. Another aspect they envision is the possible future impact of these technologies on traditional techniques due to their rapid evolution, which is why they consider this topic to be relevant to address in the curriculum of the degree.

Results of qualitative research

121 minutes of audio recordings of group interviews were documented, conducted from October to November 2023. All recordings were transcribed verbatim using a word processor. Each transcript was analyzed in the qualitative analysis software Atlas.ti based on a thematic reading for open coding, in which 14 categories and 42 subcategories were obtained (Table 1).

Table 1. Categories and subcategories of open coding

1. Learning • Autodidact • Collaborative • Diversity of learning styles	2. Social networks • Support tool • Update media • Self-taught learning media
3. Digital communication • Email • Drive • Design software and manual technique • Social networks • Teamwork • WhatsApp	4. Onboarding stage considerations • Gradual integration • Feeling of not needing it in the present • Vision of future needs
5. Professional development • Adaptability to technologies • Global competitiveness • Introductory courses on digital tools • Online Courses • Better employment prospects • Need for update • Need for improvement	6. Artificial intelligence • Change in the future • Lack of knowledge of apps for architecture • Facilitate tasks • Support tool • Eye-catching, motivation • Loss of creativity • Realistic visualization
7. Design software • Software comparison • Drawing control • Selection criteria • Efficiency • Ease of use • Greater possibilities for elaboration • Better understanding of the topic • Better visualization of projects • 3D modeling	8. Comparison with other students 9. Manual vs digital comparison 10. Creativity 11. Development of manual skills 12. Lack of knowledge 13. Technological independence 14. Concerns about technology

• Need for prior knowledge • Practicality • Precision • Preference for one or the other	

Source: Own elaboration

After open coding, an analytical reading was carried out for axial coding, from which a matrix was created to compare the interview extracts that corresponded to each coding. With the analysis and comparison of each text, patterns were identified for the reduction of categories (Table 2).

Table 2. Axial coding

Category	It is related to
Self-taught learning • It is related to the diversity of learning styles, which is manifested when the student identifies his or her own way of learning: *"I feel that a tutorial would be better and I could go at my own pace, and now, I am more of a teacher, easy, step by step, or seeing how they are doing it, but I am more of a go-back person."* • It intervenes in the mastery of digital and manual skills, since through practice students have the possibility of developing skills to use design software. • Students use digital graphical representation tools to improve their understanding of class topics. • Students perceive the need for prior knowledge of design software, so they consider incorporating it in a self-taught and gradual manner in order to be familiar when facing a job in the future: *"Start researching introductory courses for certain programs, just so as not to arrive at zero and to have an idea of more or less how to work with them."* • Social media is an important support tool for students' self-taught learning and has been used to complete their hand-made work. YouTube, TikTok and Pinterest are networks that students rely on	Digital communication: Canva Onboarding stage considerations: Gradual integration Development of manual skills Professional development: Need for update Professional development: Need for improvement Mastery of digital and manual skills Lack of knowledge Design software: Better understanding of the topic Learning: Diversity of learning styles

for their learning: *"The videos are a guide and the explanations are also a guide. So, watching the videos plus the explanation creates an easier way to understand the technique and be able to do it better."*

Manual-digital comparison

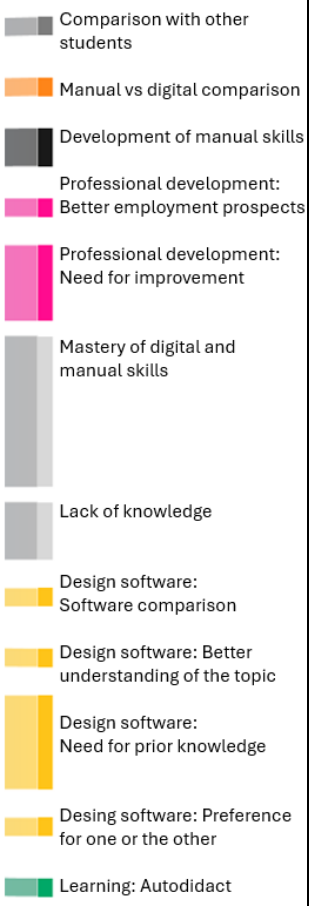
- The possibilities of modifying digital drawings in terms of reducing time compared to manual techniques: *"You can modify it as many times as you want", "the time savings and the ease of modifying things because on paper or freehand plans, well, with instruments, a mistake meant spending half an hour trying to erase it or repeat the entire sheet".*
- They highlighted the advantages of achieving greater precision with design software: *"Digital tools are more accurate than if we do it ourselves."*
- They pointed out that, although it is a slow process to learn manual representation techniques, it is necessary to strengthen the knowledge of representation and design, in order to then begin using this knowledge to manage a digital tool.
- They emphasized that learning using manual techniques and digital techniques is different and that through manual techniques they relate information better for their learning.
- Some students debated the usefulness of manual techniques, arguing that in the future these techniques would not be useful, since the use of design software provides a considerable time optimization compared to the use of manual techniques.
- Third semester students in particular expressed satisfaction at having learned manual techniques for drawing and representation, since this facilitated their transition to digital tools. They pointed out that if they had used both techniques at the same time, their attention would probably have been focused on one. In addition, they mentioned that the use of each technique will depend on the specific work case presented to them, so they must *"analyze which*

technique could be more efficient for you." Whether it is sketching, explaining an idea, presenting a sketch, making a plan, among others, they must develop a mastery of both techniques.

- Students highlighted the expressive freedom of drawing by hand, allowing for a better transmission of ideas to begin the design process.

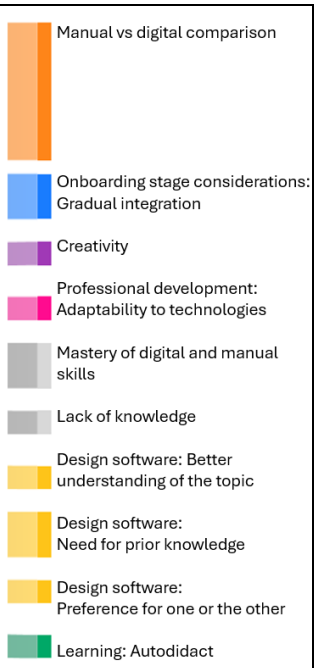
Onboarding Stage Considerations. Gradual Integration

- Students noted that the incorporation of software Design should be gradual and start with an introduction.
- When compared to other students from other courses, students expressed the need to incorporate digital tools for architecture from the first semester in an introductory manner: *"From the first semester they could introduce us to basic things so that it becomes easier for us later, because otherwise we would have to look for separate courses."*
- Students have a vision of needing to learn design software in the future, and if this is not covered by the educational program, they would do it in a self-taught manner.
- They stressed that from the first semester, while they are learning manual techniques, they could have a basic introduction to digital tools focused on design.
- They acknowledged that the effective use of design software requires time to practice in order to learn and apply the tools: *"The more you know about the tool, the easier it is to apply it," "at first it may be a bit difficult, but I think that with practice you can get there, and start using it in an easier way."*
- AutoCAD is mentioned as an ideal software to start working in design software from the beginning of the degree: *"I would have also liked to have at least one class a day a week in AutoCAD."*



Development of manual skills

- Students explained that developing manual skills takes a lot of time, but is necessary.
- Students considered that learning through manual techniques allows them to better retain representation concepts, in addition to being a practical way.
- Third-semester students pointed out that since they are not familiar with design software, they use manual techniques, which is easier for them.
- Students see greater possibilities for expression and creative freedom in manual techniques, as opposed to software, where they are limited mainly by their lack of knowledge of what can be done with it. *"That part of creativity, what is done by hand, and the tools are only there to facilitate the time and process of drawing."*
- Students are aware of the artistic essence of the career and have some concern about how technology provides tools to create what was previously done manually.
- Students mentioned that by mastering digital and manual skills, they can fully focus on developing their creative ability.
- They also highlighted that the development of manual skills provides them with technological independence towards digital tools, allowing them to solve problems without the need to use software or an application: *"Developing that skill and not always being tied to a program."*



Professional development

- For students, the use of digital tools is associated with higher levels of global competence.
- They stated that the use of digital tools can give them greater job opportunities in Mexico and other countries, which is why they perceive better employment prospects through them.
- Sketchup and Rhinoceros were mentioned by students as softwares that are used worldwide. AutoCAD was mentioned as a leading software for communication in architectural practice.
- The students identified that there is a high demand for projects in the industry, which is why there is greater efficiency with the use of digital tools for architecture: *"Looking for the easiest, fastest way to make your company work."*
- They pointed out that in addition to classes, it is important to feed their knowledge from other sources and in a self-taught manner: *"Now that we have AutoCAD, the video tutorials on YouTube have cleared up my doubts."*
- Other people's opinions are an important part of students' means of updating themselves: *"I spend a lot of time with people from higher semesters, and they are the ones who tell me, no, this tool would be better for you," "many times you receive publications or teachers telling you <<This new program is emerging>>," "on Facebook, there are many pages where they say <<What do you think about this project?>>."*
- Social media is an important means of updating. Students pointed out TikTok, Instagram, YouTube and Facebook as platforms where they find relevant architectural information, which have allowed them to learn about design software and architectural projects.
- Highlighted the initiation and mastery in the use of digital tools as a need for improvement: *"There should be at least one subject in every semester"; "We don't have that many semesters of digital tools, so we wouldn't be able to master it well."*

Lack of knowledge

- AutoCAD, Sketchup and Revit were the design software most known by the students.
- Due to the lack of knowledge of certain software, students use what is within their reach or what they know: *"Illustrator, you need to have either a student or professional account and I feel that it also has something to do with that, and maybe we haven't seen it yet so it seems like it has more complexity in that aspect than, for example, Canva*."
- Third-semester students commented that they would have liked to have had some digital tool from the beginning of their degree, since they currently lack this knowledge and are beginning to feel overwhelmed with assignments in subjects that require them to use some design software: *"The professors assume that we already know how to use it and they leave all their projects there for us."*
- They expressed their interest in the use of Artificial Intelligence (AI) and how they could use it as a tool to facilitate tasks during the design process: *"If we learn to use this tool, it would make things easier for us, or it would not make things easier, but it would be one more tool, and a very important one, that we could use when designing."*
- Students are aware that there are applications that create advanced virtual environments. They do not know the name of VR and AR applications through Oculus Rift, but they consider it to be an important technology for the visualization of projects in the very near future in the educational field: *"All that they do with virtual reality glasses, I don't know what it is called, what they use, that through an application they use this to visualize a project on a one-to-one scale, which they can even go through with this type of application. I think that is coming in the future."*

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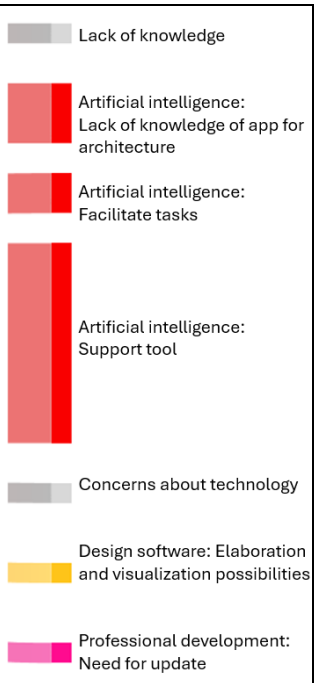
Artificial intelligence

- Some students are aware that there are architecture-focused AI applications that they can use, but they don't know which ones specifically: *"I don't know what it's called."*
- They have the perception that AI will make tasks easier for them as students and in their professional life, for the visualization of ideas during the design process: *"It will be a little easier for us students, architects, to visualize an idea that you have in mind, because you just tell artificial intelligence what you want, then it gives you a realistic image of what it would be like."*
- Students see AI applications as a support tool for the realistic visualization of architectural projects: *"It gives you the possibility of being able to better visualize projects. For example, artificial intelligence is already widely used today to be able to see the project in a more realistic physical form."*
- Students viewed AI as a support tool, rather than a tool that does their work for them: *"There is a difference between relying on artificial intelligence and leaving it completely to artificial intelligence."*
- They reflected on certain concerns, such as that the architect's work could be replaced by an AI: *"[Some clients might say] <<I just put things in and that's it, why do I hire an architect?>> But I also feel that, if we know how to use it, we can also charge you for that," "There is a misconception that artificial intelligence has come to take away jobs from many people, including us architects, when in reality this is not the case*."
- Technical drawing students mentioned that they are using some of these AI applications. By assigning parameters, they create images that they use as a reference to combine with the hand sketch and thus obtain a final image: *"We combine in a sketch what we are doing manually with the AI so that it gives us an image*."



- The use of AI is associated with the loss of creativity, as some students mentioned: *"Artificial intelligence can be a double-edged sword. You can completely base your work on it and you would either not have as much skill, or you would lose a bit of the skill, creativity that is required as an architect."*

Concerns about technology

- Students mentioned that new technologies impress them and that they will have a strong impact: *"There are some applications that can give you plants, a roof, and it really is scary."*
- Students' concerns about technology are related to the need to continually update themselves. They expressed that, due to the rapid technological advances, education in digital media is essential: *"It is kind of essential to have that education or at least, even a little bit in digital media and all that, because of the way things are moving, because it is not the same as before. I feel that, if we don't do it, we will become obsolete."*
- There is amazement, uncertainty and some concern about the AI architecture and design applications that are currently emerging: *"I was also scared that so many were coming out," "They would probably take away the artistic aspect."*
- Students mentioned that teaching with manual techniques is on the decline and that this trend will continue. In other words, there is a shift from manual techniques to the use of digital tools: *"I think that at some point we will stop designing by hand a little more, I mean, yes, we are learning it, but I think it is a little less and I feel that the need for it will decrease*."
- There is concern about focusing mainly on mastering digital tools for architecture and neglecting the design process and its purpose: *"That there are people who dedicate themselves to doing architecture, not for the design, but to have a job opportunity with these programs*. "

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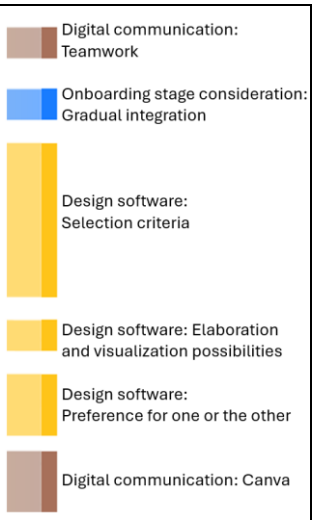
Design software: software comparison

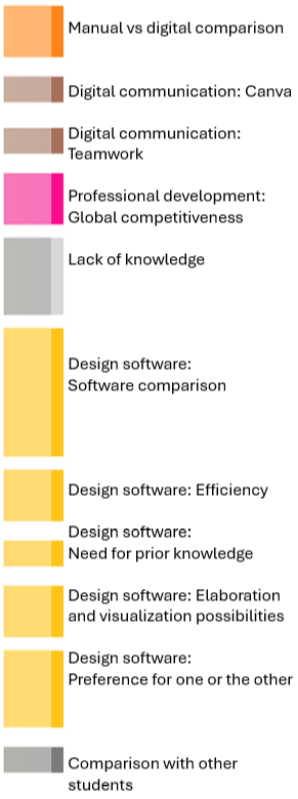
- Students viewed Revit as a software that relates to the way they design.
- They pointed out that the use of AutoCAD is focused on 2D graphic representations, while for the creation of three-dimensional representations they considered choosing software such as Sketchup: *"Sketchup could help us see something more in 3D than AutoCAD."*
- When choosing software, students said they have to weigh the pros and cons of each one, according to the work they are going to do. Evaluate what the software allows them to do and how easily, whether it allows them to make 3D models or work in teams or online. They prefer the Canva platform to make their presentations, slides or posters, since they can work as a team in real time and it has various design options unlike other tools, among which they mentioned PowerPoint or Google Slides.

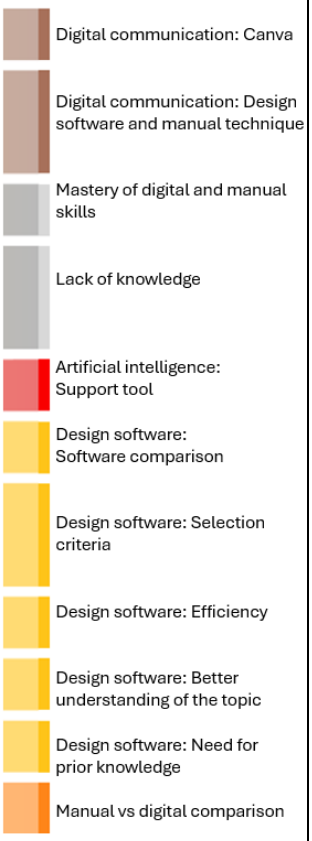


Design software: selection criteria

Students base their choice on the following when choosing a particular digital architecture tool:

- Practicality.
- Ease of use and learning.
- Access to the software: whether it is free or has a subscription for students. In some cases, unofficial versions of the software are used.
- The pros and cons of each application, software or tool. Based on research, the tool is selected according to the work to be done.
- Online teamwork.
- Because of its popularity. If it is the one that most people use (like AutoCAD), there is greater ease of communication.
- If it is current software.



• By its complexity of use, from basic to complex: *"One that begins to induce us to the next, that is, perhaps according to the degree of difficulty of each tool."* • It allows the creation of three-dimensional representations or renders, according to the work to be carried out.	
Design software: possibilities for development and visualization • Students classified some software according to the graphic representation to be made. AutoCAD for 2D representation and Sketchup for 3D representation, *"Sketchup is where you can make shapes that are not just two-dimensional,"* and with that its degree of complexity from 2D (initial) to 3D (complex). Third semester students highlighted Sketchup as a practical software to use: *"Sketchup, which is the simplest and easiest to use, for now*." • In this way, two forms of visualization are identified that emerge from this code: 1. Visualization through digital tools to better understand a class topic: *"The time we had the online class it was much clearer and more precise", "that it gave me visibility or in cuts or something like that to know how to do them."* 2. Realistic visualization through the creation of graphic representations in design software to present or view a project that students carry out: *"Artificial intelligence is used a lot to be able to see the project in a more realistic way*. "	

Source: Own elaboration

Once axial coding was completed, selective coding was performed, which consisted of relating the reduced categories to a central axis for the new emerging category. With selective coding, it was found that the incorporation of graphic representation technologies depends on the stages of the design process, so this concept becomes the central emerging category (Fig. 2). In this way, two main stages of the process can be distinguished: 1. The creative process (conceptual analysis) and 2. The development process (schematic to detailed elaboration).

Each stage is characterized by the main use of manual and digital representation techniques. Both techniques describe the ease of modification, but their advantages and

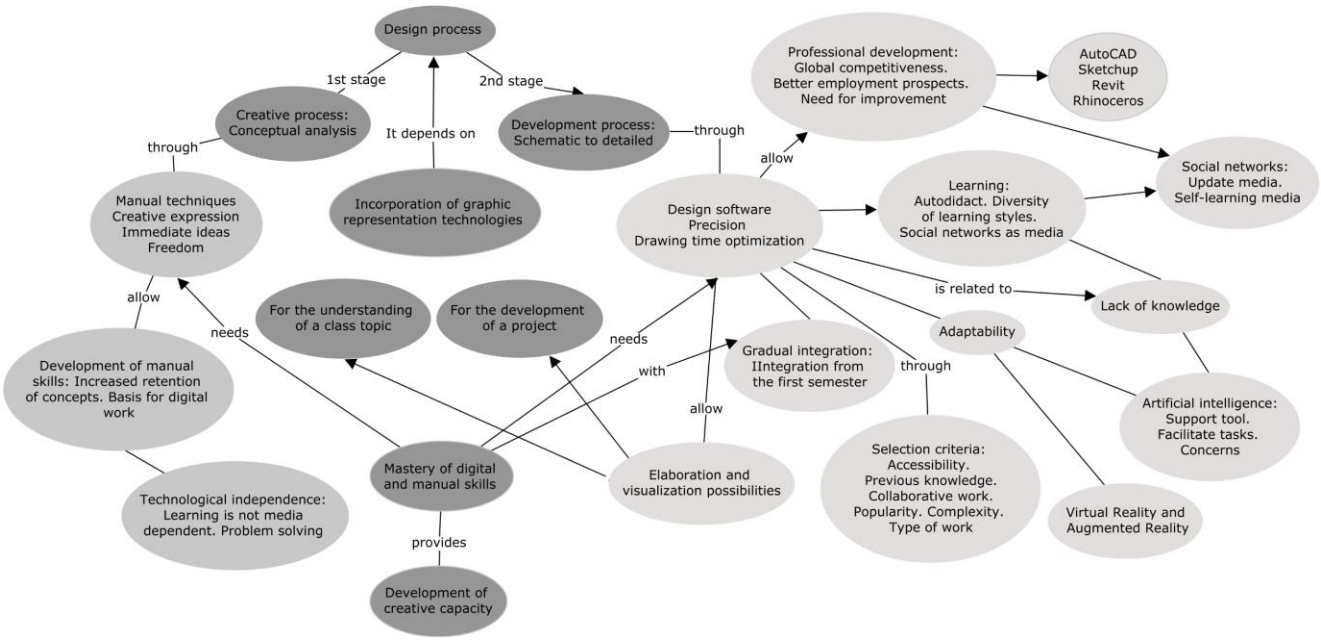
disadvantages change when applied to the design process:

1. There is ease of expression, freedom and modification of hand drawing when it is required to sketch and represent immediate ideas, which is directly related to the development of creativity.

2. Once the ideas are consolidated, a representation of the execution of those ideas is required, that is, the project. This process goes from the schematic to the detailed. Its realization is facilitated through design software due to the precision and visualization of the digital drawing.

For students, the use of digital tools for architecture represents the optimization of drawing time, while manual work is related to the creative part, and creative work is based on the intuition and sensitivity of the architect, through the understanding of social contexts, client desires and particularities for each project (Chumpitaz, 2020).

Figure 2. Diagram of selective coding



Source: Own elaboration

Discussion

From the triangulation of results of the methods used for the research (Table 3), the following conclusions were obtained about the current state of the incorporation of digital tools in the subjects focused on the graphic representation in the curriculum of the Bachelor of Architecture of the UAQ:

- Social media and video tutorials represent important means of ubiquitous learning and updating.
- Students' learning of digital tools is mainly achieved in a self-taught manner.
- There is a notable preference towards digital tools for architecture over traditional manual techniques, the main reasons being precision and time optimization in drawing.
- The need to learn traditional manual techniques for architectural representation is recognized.
- AutoCAD, Revit and Sketchup are software that students identify as important in the area and with the need to learn.
- Technologies such as VR, AR, BIM and AI applications are perceived as technologies that they would like to incorporate more into the career curriculum.
- There is uncertainty and speculation about the replacement of traditional manual techniques by the use of software and design applications.
- The incorporation of digital tools for architecture should be a gradual process from the first semester to achieve mastery of digital skills. This should be done without neglecting the development of manual skills and the design process itself.

Table 3. Triangulation of results according to DITRIAC

Quantitative research	Qualitative research
Main use of digital educational tools and social interaction. In such a way that students do not face significant challenges in using these tools.	Social media is an important means of learning and updating. Certain social media software or applications allow students to have greater control over their learning according to their needs.
Challenges related to class doubts and the computer equipment required to work with design software. Students have solved these by asking classmates and teachers, with video tutorials and by acquiring computer equipment.	Video tutorials stand out as learning tools because of the possibility of learning from them at any time and in any place, as well as the possibility of learning at one's own pace, and being able to clarify concepts or procedures.
Learning digital tools is mainly self-taught.	Due to lack of knowledge of certain software required of them, students have to learn on their own.
There is a preference for digital graphic representation due to its precision, speed and ease.	Perception of manual techniques as a time-consuming and complicated process to carry out, which is why students note their preference for design software due to its practicality, the possibility of better visualization and control of the drawing to make modifications in less time.
Use of digital graphic representation tools mainly for the preparation of plans.	The use of digital tools in architecture allows for the creation of more drawings in less time and facilitates the correction of details.
Mastering digital tools requires significant practice time, but is essential for a successful career as an architect.	Both manual and digital techniques are important for professional development, and there must be a balance between both for learning.

Preference for AutoCAD, Revit and Sketchup because they are the software they know, they perceive them as popular, practical and easy to learn.	Perception of AutoCAD as a leading software in the field. It can be difficult to use at first, but with practice it is easy to learn how to use. It provides the basis for the use of other software such as Revit or Sketchup.
VR is the most familiar to students, and they would like to include VR, AR and BIM to a greater extent in the career curriculum.	Notion of applications that generate advanced virtual environments. Students believe that these technologies will be essential for the visual representation of projects in the future.
Insufficient training to keep digital skills up to date. Students seek to acquire these skills on their own.	In addition to classes, students enrich their knowledge from various sources and through a self-taught learning process. Third-semester students pointed out that there are not enough classes on digital tools for architecture in the curriculum, which is why they are unable to acquire a mastery of them.
Introduction to the use of digital graphical representation tools from the first semester, to better understand how they work.	The gradual integration of basic design software from the first semester would allow the mastery of digital skills in parallel with manual ones.
Students found the way the curriculum is structured to be adequate, but would like to see more VR materials in the program.	Student satisfaction in having learned manual techniques for drawing and representation, since this facilitated their transition to digital tools.
Impacts on traditional techniques due to the use of new technologies and their rapid evolution, this becomes a relevant topic to address in the curriculum of the career.	Teaching with manual techniques is on the decline and this decline will continue. Students perceive the displacement of manual techniques by the use of digital tools.

Source: Own elaboration

The study on the integration of social media in architectural education has gained relevance in the search to foster the digital participation and engagement of architecture students in online hybrid education, based on an approach that recognizes design as a process of interaction and experience, in which social media can enhance levels of participation within pedagogical design (Bakir and Alsaadani, 2022). This suggests that social platforms can be strategically used to facilitate greater interaction between students, teachers, and educational content, to enrich the learning process through new forms of participation and collaboration.

The analysis carried out on the incorporation of digital tools in the Bachelor of Architecture program at UAQ coincides with the proposal of a study that was carried out on the integration of computer applications in 20 of the best international architecture schools and eight architecture departments in Egyptian universities, which revealed that 68% of these applications are included in the design studio, while 32% are taught as independent courses (Soliman *et al*., 2019). The study proposes that integrating computer applications into all years of the study plans would be more efficient.

Conclusions

This mixed-approach research allowed us to explore in depth the conditions for incorporating digital tools in a university educational context in Mexico, through the perception of architecture students. This perception indicates that the incorporation of design software, in addition to including gradual integration on a semester basis according to the needs of students, is also determined by the design process itself. The use of design software depends on the characteristics of the design process. Likewise, its use presents limitations such as the lack of knowledge and the possibilities offered by certain software, which initially requires time to become familiar with.

Given the use of social media by students for their learning, strategies are suggested to encourage active and continuous participation in classes, adapting to various educational modalities such as in-person, virtual or hybrid. This includes activities that guide self-taught learning and align with the contemporary lifestyle, in which platforms such as Facebook, YouTube, TikTok and Instagram are common elements of daily life.

It is necessary to gradually incorporate digital tools for architecture in all semesters, especially at the beginning of the degree, so that students acquire basic notions and master them in later years. To achieve this gradual incorporation, a pedagogical framework is required to

guide and moderate its proper implementation. This framework must consider the design process, since the development of manual skills must persist for the development of the creative capacity that intervenes in problem solving. Therefore, students are required to develop both digital and manual skills to meet the current needs of the construction and building industry. In this way, it can be guaranteed that future professionals have a complete and versatile training in line with current reality.

Future lines of research

It is important to acknowledge as limitations of this research the need to understand teachers' perceptions and roles in the effective integration of digital tools in architectural teaching, as well as the barriers they face when adopting and using these tools in their pedagogical practice. Therefore, future research could consider these perspectives to obtain a more complete view of the incorporation of digital tools in architectural education.

It is essential to develop lines of research that offer new approaches to the teaching-learning process of architecture in higher education, in line with current technological advances. This is in regards to digital tools that can support the learning and practice of architectural design, considering the implications that the reduction in the use of manual techniques may have and the impact of a balanced integration between manual and digital techniques.

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Contribution Role	Author(s)
Conceptualization	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Methodology	Luz Angelica Mondragon del Angel
Software	Not applicable
Validation	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Formal Analysis	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Investigation	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Resources	Luz Angelica Mondragon del Angel
Data curation	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Writing - Preparing the original draft	Luz Angelica Mondragon del Angel
Writing - Review and editing	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Display	Luz Angelica Mondragon del Angel
Supervision	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Project Management	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno
Acquisition of funds	Principal: Luz Angelica Mondragon del Angel Supported by: Sandra Luz Canchola Magdaleno