Al-Qadisiyah JournalFor Engineering Sciences 18 (2025) 249 – 256

Contents lists available at: http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: https://qjes.qu.edu.iq

Research Paper

The knowledge content of digital design subject in architecture schools

Sarraa Younis and Dhuha A. Al-kazzaz

Department of Architecture Engineering, College of Engineering, University of Mosul, Mosul Iraq.

ARTICLE INFO

Article history:
Received 15 September 2023
Received in revised form 20 April 2024
Accepted 03 July 2025

keyword:
Computation design
Digital design
Architecture curricula
Courses
Computer technologies

ABSTRACT

The emergence and spread of digital technology in architectural design and professional practice has resulted in a restructuring of architectural education. Different approaches have emerged to integrate digital design into architectural curricula. This paper aims to identify accredited digital design courses and the nature of the content provided to enhance students' knowledge and skills. The research problem revealed the diverse and different ways to integrate digital design into architectural education curricula in general, and there is no clear vision of the knowledge content of digital design courses. The research questions were determined to investigate the main aspects of digital design courses, the types of knowledge provided, and the levels of knowledge provision for these courses. To answer the questions, the study adopted a conceptual analysis of the published literature on university experiences in teaching digital design courses. The content of these courses was analyzed and revealed that the types of provided content ranges from preparing design projects at different scales, conducting exercises on implementing digital models, or presenting purely theoretical knowledge. The levels of implementing computer technology in teaching digital design range from representative, formative, generative, performative, and manufacturing levels. The relationships between traditional design education and digital design education are found in three ways: the digital design education replaces the traditional design education, the parallel application of both traditional and digital design paths or adopting digital design education later after traditional design education.

1. Introduction

Architectural design is among the disciplines that have been positively influenced by computer technologies, laying the foundation for what is known as Computer-Aided Architectural Design. This allowed architects to rapidly produce and reproduce drawings. Furthermore, it evolved to facilitate the creation of digital models, which replaced handmade ones. This also led to a reduction in time and cost when making modifications and generating numerous design options. These digital models were developed to incorporate construction information and materials. Consequently, they acquired the capability to produce two-dimensional and three-dimensional drawings simultaneously, along with the ability to calculate quantities, materials, and compare specifications [1]. Professionally, digital technologies were utilized in the past three decades to enhance architectural practice, producing high-precision drawings in a reduced timeframe. Hence, these technologies were employed in architectural schools to keep pace with this progression. Computer software influenced students' skills, practitioners' professional culture, and education [2, 3]. The notion of digital design doesn't solely focus on the relationship between design technologies. It considers the relationship between analogy and digital design tools to fully leverage digital refinement in architectural engineering. At the teaching level of digital design, it strengthens the bond between the student and the lecturer [4, 5]. Due to the evolution of digital technologies, significant shifts occurred in the teaching and practice of architectural engineering. Digital tools moved beyond being mere abstract representation tools and became defining elements of the design process. The term "computational projectör "computational design"fundamentally differs from "digital projectör "digital design."The latter represents the use of computer tools in the design process, while the former is recognized as employing computing, whether analogical or digital, in enhancing design processes [6]. Modern computational design thinking is an evolution of the approach of computer-assisted design thinking. The computer-assisted approach assumes an object-based strategy to express information in symbolic representations, while the computational approach enables the achievement of specific data. Here, the designer acts as an author for implicit description rules, which are later translated into the form [4].

1.1 The Impact of employing digital technologies on architectural design education

Digital design tools are reshaping the teaching and thinking processes in architectural education. Students interact with digital technologies on their own, even if these technologies aren't inherently part of the design studio curriculum. A common issue arises where students utilize computer programs solely as representational tools and not as instruments for synthesis [7]. The structure of architectural education comprises various courses, each with its own aims and outcomes. The design studio stands as the essence of architectural education, acting as a repository for knowledge transferred from all the other academic subjects. Here, students leverage what they have learned to enhance their skills in the design studio [8]. Architectural departments inherited the culture of architectural studio teaching from the Ecole des Beaux-Arts to replace lectures and classes used in other disciplines. Through the design studio, students develop their project ideas in the classroom using various methods. Academics aid in this endeavour, and students receive feedback on their ideas up until the end of the course term. The studio remains a central activity in the pedagogy of architectural education [4].

*Corresponding Author.
E-mail address: dhuha.kazzaz@uomosul.edu.iq ; Tel: (+964) 770-184 4334 (Dhuha Al-kazzaz)

https://doi.org/10.30772/qjes.2023.143373.1031
2411-7773

Nomenclature

AI	Artificial Intelligent	*DTS*	Design Thinking Strategy
AR	Augmented Reality	*DAD*	Digital Architecture Design
BIM	Building Information Modeling	*VAE*	Visual Algorithm Editor
CAD	Computer Aided Design	*PDT*	Parametric design thinking
CAM	Computer Aided Manufacturing	*VR*	Virtual Reality

Kalay believed that schools of architecture bear the responsibility of understanding the shifts in methods and practices due to the emergence of digital architectural design. They must also educate new generations of architects who will utilize these tools to shape the inhabited environments [9]. Angulo & Vermillion considered that digital design is a trend closely linked to information technology, and this connection continuously leads to a change in the content and form in which digital design is studied [10]. Due to technological advancements confronting educational institutions, hard-to-attain knowledge and skills are no longer sufficient by the time students graduate. Skills previously deemed exceptional have become commonplace due to the proliferation of computing, automation, and generative capabilities. Hence, architectural education requires continuous curriculum development and should not be limited to just skill enhancement [11]. Digital tools are an important part of students' knowledge development. It is essential to ensure that the course structure meets the needs of classes studying digital design tools at all levels. At a procedural level, it is about supporting students' design thinking through computational means. While on a practical level, it involves the acquisition of programming skills, enabling students to be more efficient in producing documents and other outputs [12]. Based on the above, this article reviews previous studies that dealt with offering courses related to digital design with different contents or integrating digital design into other courses, which leads to defining the study's problem, goal, and methodology.

1.2 Literature review

Previous studies have provided various experiences regarding several approaches of teaching digital architectural design in architecture colleges, Table 1. For instance, (Ceylan, 2021) proposed general perceptions of the role of artificial intelligence in architectural education. The study pinpointed the methodologies most expressive of artificial intelligence in architectural education as Building Information Modelling, physical building properties analysis, and parametric design. It discussed the impact of AI on architectural representation with the emergence of VR and AR technologies and the development of software such as Lumion, Twinmotion, and Cinema4D. Additionally, it addressed AI's influence on construction, highlighting BIM and 3D printers. The study classified the levels of AI impact on academic courses into those least affected, moderately affected, and most affected [8]. Kieferle and Woessner introduced two methods for implementing digital visualization techniques in the curriculum. The first method integrates them into design studio projects, where students are concurrently taught the Revit software in a CAAD course to use it in conjunction with virtual reality. The second method incorporates it directly within the CAAD course using simple exercises to study the scale of the building using 3DSMAX, wherein the software is taught in the same course. The study also emphasized the collaborative work via virtual reality labs [13]. On the other hand, Vamvakidis (2019) proposed two types of digital design education curricula: one focusing on digital design independently from computer applications, and the other emphasizing digital design using computer applications. The digital design without the use of computer applications is taught using "controlled transformation" methods, applied firstly for first-year students. The study also addressed teaching digital fabrication and its application in design projects [14]. Varinlioglu et al. (2016) introduced the concept of short-term workshops within the architectural education curriculum to teach digital design, applying it to simple students' projects in the early stages of the curriculum to foster analytical thinking. The study explored new teaching methods, such as experiential learning, to suit digital design instruction and the use of pre-set Grasshopper definitions [15]. The study by Lima et al. (2020) proposed using shape grammars through parametric techniques for urban design course projects. It is suggested that the subject be taught in a separate course that combines students from two specializations, architecture and landscape. Within this course, students would be taught Shape Grammars and software tools like Rhino and Grasshopper [16].

1.3 Research problem

Based on reviewing previous studies, it becomes clear that there is a clear trend to adopt digital design in architectural education courses. There is variation, diversity, and disparity in the knowledge content provided in digital design courses. The paper identified the research problem around the lack of a clear vision regarding the nature, level, and type of knowledge these courses provide. A set of research questions is put forward. What are the main aspects of digital design courses in architecture schools? What is the nature of the knowledge provided in the courses? What are the levels of knowledge provision for digital design courses?

1.4 Research objectives

As a result of the emergence of digital technologies and the transformations they have brought about in architectural design and practice, the need has emerged to develop educational curricula for architectural schools, and to integrate digital design as an essential element of architectural knowledge. This paper aims to investigate the approved courses for teaching digital design and to identify the content provided in these courses to enhance students' knowledge and skills, and thus support their future professional practices.

2. Methodology

To answer the questions raised in the research problem, the paper adopted a thematic analytical approach of published literature on courses that teach digital design, as well as university experiences in teaching digital design in architectural schools. This entails analyzing the content of these courses and the nature of the knowledge provided, and ultimately identifying some aspects of the knowledge content provided in these courses.

3. Content of digital design courses

Xiang et al. concluded that one of the most critical axes of digital architectural design curricula is the "type", which reflects the course content and the knowledge conveyed within the course. The study classified three kinds of content: "teaching software applications and the use of design software", "teaching digital design method and theory", and "teaching the application of computer technology and digital design methods" [17]. In order to analyse the content of the courses, several experiments presented at a number of universities and with varied digital content were selected. In their study, Juniora and Carvalho, in their study, provide a description of an introductory course at PUC Minas University in Brazil that encompasses teaching creative techniques to students. This teaching involves introducing an approach focused on the fundamental and essential aspects of space, the relationship between physical form and space, the interplay between space and nature, the connection between nature and geometric form, and the link between space and structure. Students are trained using creative techniques through a series of quick exercises that emphasize digital creation processes. These exercises aim for students to accomplish drawings manually, alongside digital modelling and the preparation of initial prototypes. In the same study, students apply what they've learned to two specific projects designed for the course using digital techniques: the first project revolves around the design of a public plaza situated in the context of a residential neighbourhood. This environment, characterized by gently sloping terrains and specific solar orientations, necessitates a focus on thermal comfort. The challenge for the students is to create, delineate, qualify, and connect open free spaces. The second project represents the design of a pavilion within the university campus, configured somewhat like a mini-forest. It features medium to tall trees placed at irregular intervals.

However, amidst these trees lie expansive spaces and vast areas as shown in Fig. 1 and Fig. 2, [18]. Vamvakidis incorporated the teaching of digital thinking methods at Plymouth University in the UK, such as the controlled transformations method, to instruct students on how software-based thinking operates. For the first phase in the design studio, the outcomes of the initial semester were physical models complemented by layout drawings and sketches. In the following semester, the results evolved into digital models along with layout drawings, using the Rhinoceros software. Students were introduced to modelling methods in Rhinoceros during the first two weeks of this second semester. Additionally, they were familiarized with Computer Aided Manufacture methods [14]. This teaching approach was also applied in the second phase of the design studio, focusing on a multi-unit residential project. Here, students were initially briefed about controlled transformations and the theory of computer-aided design through a studio lecture [7].

Table 1. Summary of literature review.

Research title	Author	Research problem
Artificial Intelligence in Architecture: An Educational Perspective.	Ceylan [8]	Find the levels of impact of introducing digital design on educational curriculum courses.
Virtual Reality in Early Phases of Architectural Studies Experiments with first year students in immersive rear projection based virtual environments.	Kieferle & Woessner [13]	This paper addresses the question of how projection based immersive Virtual Reality in Powerwalls and CAVEs can be integrated into the early phases of architectural education.
Computational Design Thinking for first year architectural design studios.	Vamvakidis [14]	The paper discussed two types of teaching computational design to first-year students: computational design independently of computer applications, and computational design using computer applications.
Computational Thinking and the Architectural Curriculum Simple to Complex or Complex to Simple?	Varinlioglu et al. [15]	The paper deals with teaching digital design through a short workshop and application to simple student projects.
World Studio: a pedagogical experience using shape grammars and parametric approaches to design in the context of informal settlements.	Lima et al. [16]	The paper discussed the use of parametric digital design and shape grammar in urban design projects.

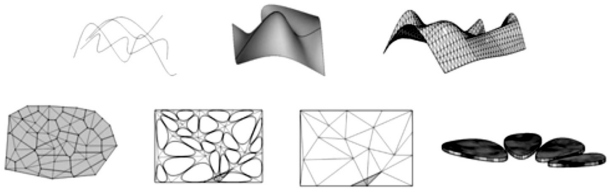

Figure 1. Generation studies for the pavilion project [18].

Figure 2. Final model of the pavilion project [18].

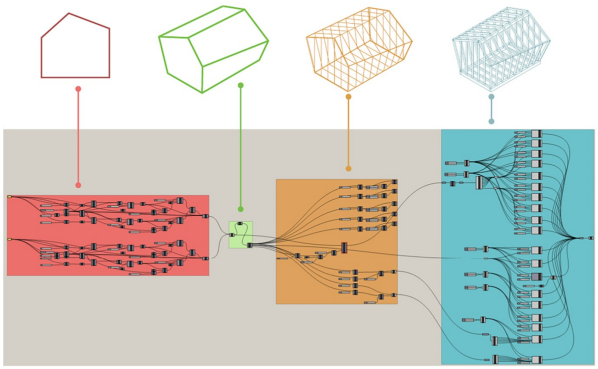

Figure 3. Modelling process of parametric reference unit [19].

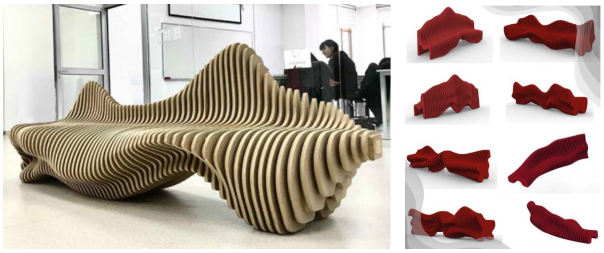

Figure 4. Initial drawings and final form of the workshop project [20].

Figure 5. Examples of parametric strategies used in the course [21].

In a study by Ponzio et al. 2020, when teaching digital design, an application was made on a design studio project, which entailed the landscape design for a hotel along with the design of hospitality units. The Parametric Design Thinking strategy was employed to aid students in developing, representing, and realizing the intricate non-planar shape details during the design of individual hospitality units. This was done by relying on the use of a "parametric reference unitäs shown in Fig. 3. In the design ideation phase, analogy design thinking was employed to form the overarching project concept. As for the computational modelling phase, the site design was outlined using AutoCAD/Sketchup, and an introductory overview of shaping principles was delivered to guide the students' explorations of the prototype hospitality unit model. In the third, material construction phase, the project was transferred to the Rhinoceros platform as initial lines. This was followed by a transition to Grasshopper, converting those lines into surfaces, and subsequently starting the design development using the "parametric reference unit". Further, the structural details of the project were elaborated to determine the construction components through linking Grasshopper with ArchiCAD. In another experiment, the BIM strategy was also utilized in project design, wherein analogical design played a role in establishing the general idea of the project. This was followed by shape generation studies exploration through analogical exercises and digital exercises (CAD - Sketchup) before leveraging a BIM reference unit to clarify the employed structural system concept to the students [19]. In Agirbas's study, the knowledge introduced in the elective workshop specialized in parametric design encompassed the design project from the modelling phase, using various software, to material selection, manufacturing of product parts, and assembly. Initially, software was selected based on students' prior experience, concepts and designs were presented through the chosen program (SketchUp, 3DsMax, Rhino, Grasshopper). Two groups utilized parametric design environments. In their design process, they adopted pre-existing elements and scripts, which were then discussed and refined with students. Essentially, students practiced parametric design thinking in these computer drawings. They used Grasshopper and Rhino software and saved all parts in a 2D DWG format. As shown in Fig. 4, one of the student models was chosen for execution and manufacturing [20]. In the parametric design workshop at the University of Della Calabria in Italy, offered to senior students, there was an aim to strike a balance between morphological and functional complexity and technology. A single architectural element, the architectural envelope, was focused on, representing its formative, technical, and symbolic values within the realm of parametric design. The proposal was to design a section of the envelope measuring 3 meters by 1 meter as shown in Fig. 5. Design choices for these attributes were also left to the students to enhance their understanding of the relationship between technology and architectural form. The architectural form of the envelope was subject to certain design criteria in addition to traditional requirements of the architectural envelope,

such as protection from solar radiation. The workshop relied on the use of Grasshopper and Rhinoceros, preceded by an introduction to the theoretical aspects of the parametric approach. All groups participating in the workshop proposed a parametric design for a section of the architectural envelope, integrating multiple modelling strategies [21].

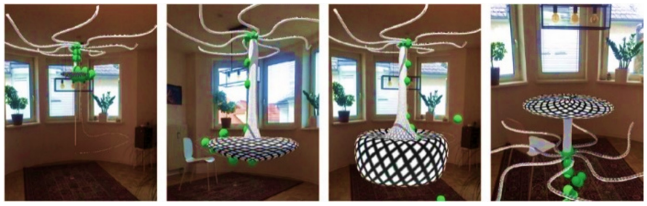

Figure 6. One of the students' results in the course [22].

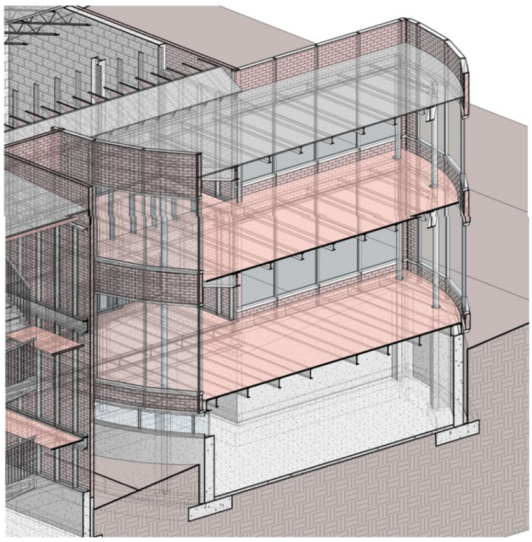

Figure 7. Final submission of the form by a student [23].

Figure 8. Example "Patterned Screen" assignment [10].

In Weissenböck's experiment regarding the use of augmented reality AR in a design project, specialized activities were incorporated for domestic spaces dedicated to students as shown in Fig. 6. The process involved a direct connection between 3D modelling software (Rhinoceros3D) and parametric design (Grasshopper) on computers, and Fologram on mobile devices. The course began with introductory lectures on augmented reality and its applications in architectural engineering. Subsequently, students were trained on the software to enhance their technical proficiency. This instructional phase included the use of the Fologram application on smartphones and computers, exploring sample files in Rhinoceros and Grasshopper, and explaining how to synchronize models and parameters between devices. The process of placing digital objects in real space using physical QR codes or ÄrUco"markers was also elucidated. Each group then worked on developing a joint design concept (geometric or functional), followed by a joint 3D model aligned with a Grasshopper definition. This led to the establishment of variable parameters, after which individual design concepts were adapted according to specific spaces and requirements [22]. In the study by Harfmann (2021), students are introduced to foundational principles and the hierarchical sequence of structural frameworks as shown in Fig. 7 in an introductory course in the logic of structure through parametric modelling. It delves into how structural knowledge can impact design. Additionally, students are educated on fundamental materials, construction methodologies, and the rationale behind construction as it correlates with design. The curriculum also covers concepts of parametric building information modelling and virtual design. The overarching objective of the course is to continuously reinforce the concept of modelling's relationship with construction layers as structural systems [23]. The digital design course ARCH263 at Paul State University emphasizes introducing the concept of parametric thinking in traditional design processes. The aim is to expand the boundaries of conventional design thinking to elucidate the relationships between design aspects and their components. Parametric thinking necessitates that designers explain how components are interlinked, how variables are adjusted, and/or the relationships between these variables, thereby generating alternative solutions responsive to the same context.

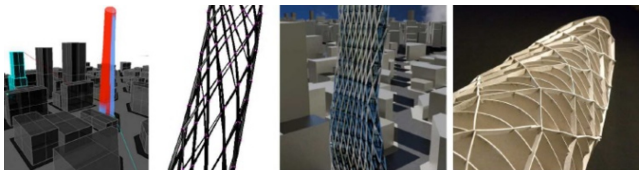

Figure 9. Example "Urban Tower" assignment [10].

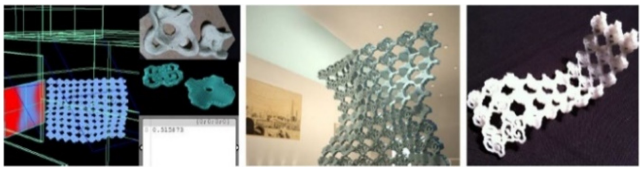

Figure 10. Example "Undulating Wall" assignment [10].

In this manner, parametric thinking bolsters evaluation and modification processes that students often overlook. This is applied through design tasks that focus on using ornamentation and repetition as design elements. The tasks vary, starting with the design of a "Patterned Screen"to display sunlight through an existing building facade. The tasks encompass three phases: the graphic pattern composition, the exterior rendering of the screen, and the laser-cut scaled panel prototype of the initial model as shown in Fig. 8. Secondly, there's the design of an Ürban Towerßhape with an engraved structural envelope as shown in Fig. 9. The fabrication focus of this design task was on creating prototypes for 3D assembly from 2D components. This consisted of several stages, starting with site testing, followed by the development of the structural system, then the exterior presentation, and culminating in the laser-cut model [10]. Thirdly, students designed solid three-dimensional components that were assembled into a "Wavy Wallßystem as shown in Fig. 10. This process had several stages, beginning with the physical representation of the components, then digitally using Rhinoceros, followed by Grasshopper, the internal presentation, and finally culminating in a 3D printed model [10]. Meanwhile, in the Algorithmic Design Approach course offered at the Bandung Institute of Technology, the focus is on introducing computational design thinking, formal language methods, and computational techniques for exploring and analysing design forms through algorithms. The course starts with a theoretical lecture on the logic and principles of computing using a top-down approach. This is followed by a practical exercise on the logic of GH VAE workflows, their structures, and formulation, in addition to data management, processing, and geometric parameters. Implementation occurs on two projects:

- An individual project where the student is required to design, develop, or explore scripts within GH VAE with an architectural application, such as a wall or shelter roof pattern. They then present panels visualizing the computational process and its outputs.
- A group project to design and build a miniature model of a shelter based on a parametric and algorithmic process as shown in Fig. 11, [24].

In a study described by Ponzio et al. (2021), a specialized course in parametric design titled "RG-III"was offered at a Brazilian university to second-level students. The course introduced students to computational thinking by focusing on processes rather than only tools. It began with theoretical lectures followed by preliminary exercises aimed at understanding algorithmic logic. Subsequently, students were introduced to two sets of software tools, with a focus on the Rhino/Grasshopper tool. They familiarized themselves with the software

components using existing reference models. The course culminated in a group project where students, organized into teams, developed a parametric set of architectural elements found in city parks [6].

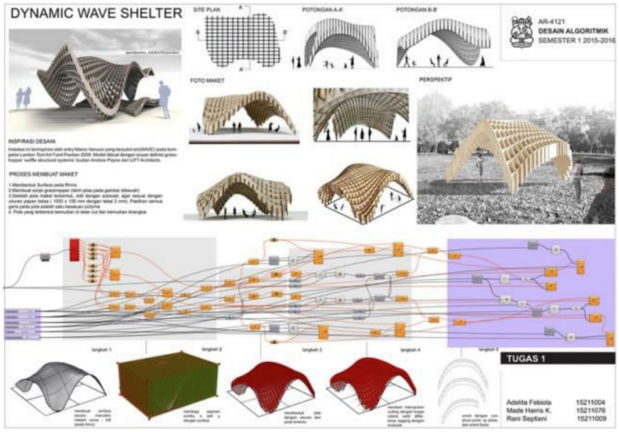

Figure 11. Student Works on Algorithmic Approach [24].

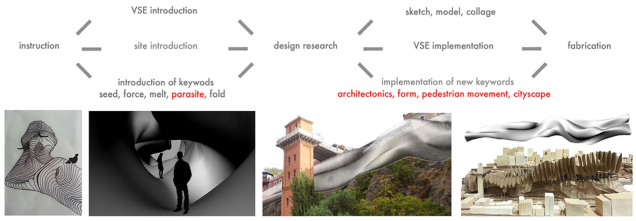

Figure 12. Design and fabrication process from the second workshop [15].

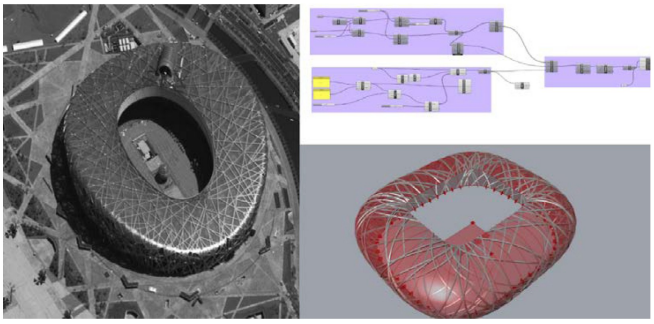

Figure 13. Parametric representation exercise of a contemporary building [25].

In another study by Varinlioglu & Turhan (2018), an important workshop called "Mars 2024"was held. It aimed to design a structural biological system that would serve as a habitat for early settlers on Mars. Students were tasked with interpreting a specific design scenario through biological simulation methods. Lectures were presented on the geographical and climatic conditions, biological simulation, digital design, and manufacturing tools. The students were required to design a growing pattern and an individual unit in this context. They integrated various digital design and manufacturing techniques to develop unique designs [26]. Furthermore, in a study by Varinlioglu et al. (2016), computational design was introduced in a workshop titled "Magnetic Envelope Formations". The objective was to explore cyclical relationships between computational definitions of magnetic force, their applications in model-finding processes, and digital model fabrication using laser cutters. Students were given a simple design challenge with few constraints, concentrating on skill-building. They were tasked with designing a children's playground by deconstructing and exploring the overall algorithm of the magnetic field. The magnetic behaviour, along with some contextual requirements, was introduced within Grasshopper VSE. Pre-set Grasshopper definitions and the specific design task allowed students to explore design methods and computational analytical thinking. They were encouraged to experiment with models by altering parameter values. The workshop then shifted to digital manufacturing crafted using available CAD/CAM tools in the modelling laboratory [15]. Subsequently, a workshop titled "VERTI Calgorithm"was organized, complementing the first workshop. The goal of this workshop was to design elements of vertical movement within the urban context of the city of Izmir. The focus was on determining the level of intervention concerning terrains, landscapes, urban vistas, and historic city views. Participants were introduced to the fundamental concepts of algorithmic design thinking and CAD/CAM tools. These groups were then given the opportunity to apply this knowledge to develop solutions for the posed design challenges, with applications directly related to the students' urban design studio project as shown in Fig. 12. Predefined Grasshopper definitions for three key terms—force, melt, and parasite—were provided, while other groups were tasked with researching and creating their own VSE definitions. Alongside these, five mandatory core concepts from computational design were introduced. Additional architectural/design concepts were added to assist students in developing preliminary design ideas. Student groups' approaches varied—some searched for diverse alternatives within the same predefined definition, thereby elevating the definition to a broader spatial level within the urban context. Initiating designs based on singular keywords and VSE definitions led to more competitive and creative outcomes during the design process [15]. Students of the Architecture Faculty at GDAŃSK University of Technology in Poland are taught the basics of parametric design and visual programming in their first two semesters. This is accomplished using practical exercises tailored for the course, preceded by a lecture on the 3D Grasshopper software, providing students with foundational knowledge of its programming and modelling a geometric dome as a course exercise. In the Advanced Computer-Aided Design course, students are introduced to the role of parametric design in the phases of design and construction through automation processes. The lessons address the parametric representation of three contemporary architectural buildings as shown in Fig. 13, along with a set of exercises related to abstract geometric concepts. A range of methods is presented, enabling students to design facades, such as panelization and Voronoi diagrams. Due to the course's limited duration, exercises are primarily focused on basic 3D modelling, integrating daylight illumination, energy simulation, construction emulation, and design optimization fundamentals. Furthermore, parametric design is also presented through seminars aiming as shown in Fig. 14 to solve specific problems, addressing the digital design process from both theoretical and practical perspectives [25].

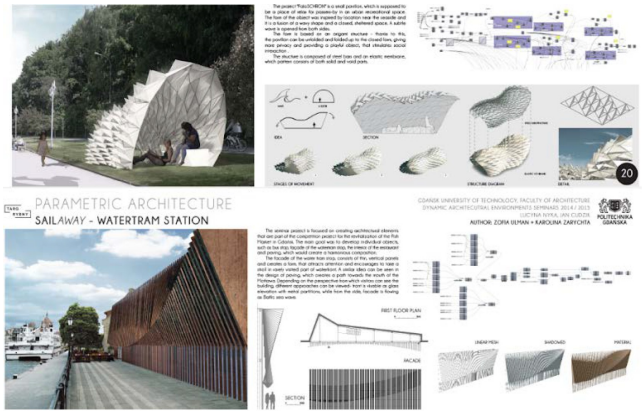

Figure 14. Students' work prepared for exhibition from the Parametric Design elective seminar [25].

4. Results and discussion

By reviewing the published literature and the experiences of universities in digital design education, the content of the courses that introduce digital design that has been defined from several aspects: the type of content provided in the course, the level of employing computer technologies in modelling the digital design project, and the relationship between digital design education and traditional design education.

4.1 Type of digital design course content

Based on past experiences in digital design education, the content of the courses that using digital design approaches ranges from implementation on design projects, providing theoretical knowledge, presentation of applicable design

knowledge, reliance on ready-made models for application, among others, Table 2.

Table 2. Type of digital design course content.

The type of content offered in the digital design studio course.	Design project	Project source	Preparing a new design project for the course
			Redesigning a previous course project
			Redesigning a real project
			Other
		Project function	Residential project
			A specific element of the project (e.g. building envelope)
			Architectural elements in a city park
			Landscape projects (children's playground - landscape for a hotel project)
			Hosting modules
			Urban design project
			Public squares
			Other
	Quick exercises that focus on digital generation processes		
	Practical design knowledge applicable to digital design		
	Digital model ready to use		
	Theoretical design knowledge		
	Other		

4.2 The level of employing computer technologies in digital design project modelling

Referring to Oxman's classification (2008) of the methods of employing computational techniques in digital design processes, which are categorized into three types: formative models, generative models, and performance models, Table 3. In digital formative models, Oxman identifies two digital techniques in this model: formatting through animation techniques, which introduced the concept of "dynamic design,änd formatting through parametric configurations that reflect the concept of topological variations. On the other hand, the generative models for digital design are characterized by employing computer mechanisms to derive design alternatives, such as generative processes or formative rules. Lastly, the performance models for digital design rely on a wide range of digital tools for simulating, analysing, and evaluating performance aspects in the design project [27]. Through analysing the experiences in digital design studios presented in previous studies, this paper identified five levels of employing computational techniques in the digital design project. These are: the use of digital techniques at the representation level, the formation level, the generation level, the performance level, and the manufacturing level. In the study by Juniora and Carvalho (2021), digital techniques are implemented at three levels: representational, formation, and performance-based. Modelling is facilitated using the SketchUp software, supported by tools such as Curviloft, S4U to Components, Bezier Curve, and Fredo Scale. These tools enhance the dynamism and flexibility of modelling, thus ensuring greater efficacy [18]. Ponzio et al. (2020) present a pedagogical experiment wherein digital design is initially introduced at the representational level. In the subsequent phase, the curriculum shifts focus to algorithmic generative processes, relying on algorithmic models founded on the Shape Grammar method and establishing parametric reference units [19]. The research conducted by Agirbas employed digital techniques at the formation level using parametric design environments. Design processes integrated ready-made elements and texts, subsequently evolving designs through these elements [20]. Similarly, a workshop showcased in a study by Canestrino et al. (2021), concerning parametric design at the University of Calabria, integrates digital techniques at the parametric formation level. This involves representing formal, technical, and symbolic values. Additionally, the performance level was accentuated by adding new requirements tied to parametric approaches, such as a modelling strategy allowing varying degrees of sunlight permeability [21]. In Weissenböck's augmented reality experimentation, digital techniques are utilized at the representational level through augmented reality AR software applications. Additionally, the parametric formation level is also explored through design ideation modelling [22]. Varinlioglu et al.'s (2016) workshop on "Magnetic Envelope Formationsänd the VERTI Calgorithm workshop integrate digital techniques at the algorithmic generative level based on shape grammars [15]. Whereas, the study by Varinlioglu & Turhan (2018) operates at the algorithmic generative level based on evolutionary processes [16]. As for teaching digital design at the University of Plymouth in the United Kingdom, it is applied to design studio projects in the second semester, and it is done at the formation level and the manufacturing level [2], while applying it to the residential project in the design studio for second-stage students is done at the formation level only [7]. The implementation of design projects in (Harfmann, 2021) was at in representational level by clarifying the structural principles and relationships between elements and the continuous enhancement between modelling and building layers as structural systems [23]. The study of (Ponzio et al. 2021) applied digital design at the representation and parametric level by adopting ready-made reference models in order to develop a parametric group of architectural elements in the city park [6]. The course of the University of Liège in Belgium depends on the generative algorithm level through the analysis and integration of mathematical theories, as it helps students to define the morphological structure of the model object, as well as on the representational level by adopting AR in showing the design concept. In the courses of the GDAŃSK University of Technology in Poland, the course is taught at the formation parametric level [25].

Table 3. The level of employing computer technologies in digital design project modelling.

Level	Models	Description, (model)
Representation	CAD	Cad descriptive
		Virtual and augmented reality
		Others
Formation	Parametric	Topological formation
		Associative design formation
		Others
	Sculpting	mesh-based geometry
		voxel-based geometry
		Others
Generation	Algorithmic	Evolutionary design
		Shape Grammar
		Parametric design
		Others
Performance	Simulation	Environmental performance simulation
		Functional performance simulation
		Structural performance simulation
		Others
Manufacturing	CAM	laser cut
		Others

Table 4. Relationship between traditional design education and digital design education.

The relationships between traditional design education and digital design education.	The process of teaching digital design replaces the process of teaching traditional design.
	The process of teaching digital design is in parallel or merged with the process of teaching traditional design.
	The process of teaching digital design follows the traditional design education process.

4.3 The relationship between traditional design education and digital design education

The relationship between traditional design education and digital design education exhibits diverse dynamics, Table 4. Teaching digital design can replace teaching traditional design, work in parallel or merged, or work sequentially. In a study conducted by Juniora and Carvalho (2021), evidence underscored the importance, potential, and efficiency of utilizing digital tools throughout all stages of the design process, rendering it a fundamentally digital endeavor. This study accentuates the need for innovative thinking, testing, and assessing novel pedagogies for design instruction, diverging from traditional methodologies [18]. Ponzio et al. (2020) relied on conventional design methods at the outset of the design phase. They incorporated an analogical design thinking strategy to develop the project's preliminary concept, then transitioned to digital design in the subsequent stages of the design process [19]. In the course introduced by Juniora and Carvalho in their research, the objective was to first accomplish the drawings manually, complemented by digital modelling [18]. At Paul State University's digital design course, ARCH263, there is an emphasis on introducing the concept of parametric thinking in traditional design processes. The goal is to push the boundaries of conventional design thinking, elucidating the interconnections among design aspects and components. Parametric thinking necessitates clarifying how things are interconnected and how variables or their interrelations are modified to generate alternative solutions that respond to the

same context. Thus, parametric thinking bolsters evaluation and modification processes, which are often overlooked by students. The ultimate objective is to catalyse a cognitive shift in students' design thinking, transitioning from viewing the model purely as an aesthetic concern to understanding and appreciating the intricate ties and dependencies between form, materials, and performance [10]. In the course offered at the University of Liège in Belgium, traditional design is initially adopted through sketches, followed by a transition to the digital design phase [28]. In contrast, courses at GDAŃSK University of Technology in Poland have fully embraced digital design [25].

5. Conclusion

The increasing role of digital design within the architectural profession necessitates the integration of digital design approaches in architectural design education. Consequently, this paper aims to explore the content of digital design courses within architectural curricula. An examination of the published literature and the curricula of universities that have adopted digital design instruction was undertaken. A thematic analysis of the studies addressing this topic was conducted, coupled with a discussion of the course content. The paper defined the content of the digital design by emphasizing variable aspects such as:

- The type of content presented in the course, such as design projects, digital exercises, theoretical or practical knowledge, or a ready-made digital model.
- The degree to which computer technologies are employed in the design and modelling of digital projects, which can be classified into five levels: representational level, formation level, generation level, performance level, and manufacturing level.
- The relationship between teaching digital design and teaching traditional design can range from replacing the traditional design education process with the digital design education process, paralleling or merging digital design education with traditional design education, or digital design education is subsequent to traditional design education.

These investigations can be extended to other facets of digital design education. There is a need to evaluate the status quo of Iraqi universities and the type of content offered in digital design courses, aiming to present forward-looking insights for their enhancement.

Notes:

- Virtual Reality: is one of used technological trends in recent education, it provides an immersive environment for architectural education, its used to simulate projects and analyse alternative solutions to improve the design process [29].
- Augmented Reality: is one of the technological trends used in recent education, which is the opposite of virtual reality, as augmented reality works to overlay virtual models with the real environment in the design process [22].
- Fologram: It is a newly developed program that helps students use AR systems at home with personal computers and smartphones and works with the 3D modelling program Rhinoceros3D and the algorithm editor Grasshopper, which are very common tools in contemporary architecture, and therefore can be easily integrated into established workflows [22].
- GH VAE: It is Visual Algorithm Editor in Grasshopper programme [24].

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

Funding source

This study didn't receive any specific funds.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

[1] A. s. Mohamed, "Digital design technology and its impact on contemporary architecture, in light of digital architectural trends," *Journal of Architecture, Arts and Humanitic sciences*, vol. 7, no. 34, pp. 1–27, July 2022. [Online]. Available: https://doi.org/10.21608/mjaf.2021.51703.2092

[2] S. Soliman, D. Taha, and Z. E. Sayad, "Architectural education in the digital age computer applications: Between academia and practice," *Alexandria Engineering Journal)*, vol. 58, no. 2, p. 809–818, 2019. [Online]. Available: https://doi.org/10.1016/j.aej.2019.05.016

[3] R. Ahmed, K. Mahmoud, K. Alahmady, and R. Mohamed, "Green education's role in advancing sustainable architectural practices," *Al-Qadisiyah Journal for Engineering Sciences*, vol. 18, no. 2, pp. 131–139, 2025. [Online]. Available: https://doi.org/10.30772/qjes.2024.153695.1393

[4] M. A. Tedjosaputro, "Concerning digital design in architectural pedagogy," *in IOP Conf. Series: Earth and Environmental Science*, 2020. [Online]. Available: https://doi.org/10.1088/1755-1315/490/1/012011

[5] A. Hammadamin and J. Nordin, "Learning challenges of architectural education in the early twenty-first century: A systematic literature review," *Al-Qadisiyah Journal for Engineering Sciences*, vol. 17, no. 4, pp. 339–351, 2024. [Online]. Available: https://doi.org/10.30772/qjes.2024.149312.1220

[6] A. P. Ponzio, M. G. Gonzaga, M. Vale, U. M. Bruscato, and W. Mog, "Parametric design learning strategies in the context of architectural design remote teaching," *in XXV International Conference of the Iberoamerican Society of Digital Graphics, Blucher Design Proceedings*, vol. 9, no. 6, pp. 1077–1088, 2021. [Online]. Available: https://doi.org/10.5151/sigradi2021-189

[7] S. Vamvakidis, "Computational design thinking and controlled transformations, for the schematic design of a second year, multi-unit housing design studio," *in Congreso SIGraDi 2020*, 2020. [Online]. Available: https://doi.org/10.5151/sigradi2020-86

[8] S. Ceylan, "Artificial intelligence in architecture: An educational perspective," *in Proceedings of the 13th International Conference on Computer Supported Education*, vol. 1, pp. 100–107, 2021. [Online]. Available: https://doi.org/10.5220/0010444501000107

[9] T. B. de Vasconselos and D. M. Sperling, "Notes on digital architectural design in the undergraduate teaching in brazil," *in Architecture in the Age of the 4th Industrial Revolution - 37th eCAADe Conference and 23rd SIGraDi Conference*, vol. 1, pp. 147–154, 2019. [Online]. Available: https://doi.org/10.5151/proceedings-ecaadesigradi2019_481

[10] A. Angulo and J. Vermillion, "Strategic thinking on the redesign of a foundational caad course:towards comprehensive training on digital design," *in Digital Physicality: Proceedings of the 30th eCAADe Conference*, vol. 1, 2012. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2012.1.029

[11] L. Basarir, "Modelling ai in architectural education," *Gazi University Journal of Science*, vol. 35, no. 4, pp. 1260–1278, 2022. [Online]. Available: https://doi.org/10.35378/gujs.967981

[12] D. Holzer, "Teaching computational design and bim in the age of(semi)flipped classrooms," *Proceedings of the 24th International Conference on Computer-Aided Architectural Design Research in Asia*, vol. 2, pp. 715–724, 2019. [Online]. Available: https://doi.org/10.52842/conf.caadria.2019.2.715

[13] J. Kieferle and U. Woessner, "Virtual reality in early phases of architectural studies experiments with first year students in immersive rear projection based virtual environments," *in 37 Education and Research in Computer Aided Architectural Design in Europe and XXIII Iberoamerican Society of Digital Graphics*, no. 1, 2019. [Online]. Available: https://doi.org/10.5151/proceedings-ecaadesigradi2019_399

[14] S. Vamvakidis, "Computational design thinking for first year architectural design studios," *in 37 Education and Research in Computer Aided Architectural Design in Europe and XXIII Iberoamerican Society of Digital Graphics, Joint Conference*, no. 1, 2019. [Online]. Available: https://doi.org/10.5151/proceedings-ecaadesigradi2019_043

[15] G. Varinlioglu, S. M. Halici, and S. Alacam, "Computational thinking and the architectural curriculum simple to complex or complex to simple?" *International Conference: Complexity and SimplicityAt: Oulu School of Architeture, Oulu, Finland*, vol. 1, pp. 253–259, 2016. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2016.1.253

[16] F. Lima, N. Muthumanickam, M. Miller, and J. Duarte, "World studio: a pedagogical experience using shape grammars and parametric

approaches to design in the context of informal settlements," *in SIGraDi 2020 - Transformative Design*, 2020. [Online]. Available: https://doi.org/10.5151/sigradi2020-87

[17] X. Xiang, X. Yang, J. Chen, R. Tang, and L. H. Hu, "A comprehensive model of teaching digital design in architecture that incorporates sustainability," *Sustainability*, vol. 12, no. 20, pp. 1–29, December 2020. [Online]. Available: https://doi.org/10.3390/su12208368

[18] S. Junior and D. Carvalho, "Digital creativity: Pedagogical strategies for design teaching," *in Proceedings of the XXV International Conference of the Ibero-American Society of Digital Graphics*, vol. 48, no. 13, pp. 2652–2661, 2021. [Online]. Available: https://doi.org/10.5151/sigradi2021-61

[19] A. Ponzio, L. de Souza, V. Schulz, and C. Lasso, "Digital understandings in the construction of knowledge report of experiences in contemporary a rchitectural design teaching," *Architecture and Fabrication in the cognitive age - Proceedings of the 38th eCAADe Conference*, vol. 1, pp. 675–684, 2020. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2020.1.675

[20] A. Agirbas, "Teaching methodology for parametric design: A case study with parametric bench," *in SIGraDi 2020 Proceedings of the 24th conference of the Iberoamerican Society of Digital Graphics*, vol. 132, no. 4, p. 041009(9p), 2020. [Online]. Available: https://doi.org/10.5151/sigradi2020-99

[21] G. Canestrino, S. Miraglia, G. Perri, and R. Lucente, "Parametric strategies in an architectural design workshop," *in XXV International Conference of the Iberoamerican Society of Digital Graphics*, vol. 177, p. 107573, 2022. [Online]. Available: https://doi.org/10.5151/sigradi2021-115

[22] R. Weissenböck, "Augmented quarantine an experiment in online teaching using augmented reality for customized design interventions," *in Proceedings of the 39th eCAADe Conference*, 2021. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2021.2.095

[23] N. Bushra, "A comprehensive analysis of parametric design approaches for solar integration with buildings: A literature review," *Renewable and Sustainable Energy Reviews*, vol. 168, p. 112849, 2022. [Online]. Available: https://doi.org/10.1016/j.rser.2022.112849

[24] A. Indraprastha, "Learning to know and think: Computing for architecture course," *in SHS Web Conf.International Conference on Architectural Education in Asia (eduARCHsia 2017)*, vol. 41, no. 05001, p. 8pages, 2018. [Online]. Available: https://doi.org/10.1051/shsconf/20184105001

[25] K. Radziszewski and J. Cudzik, "Parametric design in architectural education," *World Transactions on Engineering and Technology Education*, vol. 17, no. 4, pp. 448–453, 2019.

[26] G. Varinlioglu and G. Turhan, "A comparative study of formal and informal teaching methods in the digital architectural curricula," *Proceedings of the 36th International Conference on Education and Research in Computer Aided Architectural Design in Europe*, vol. 1, no. 1, pp. 409–416, 2018. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2018.1.409

[27] R. Oxman, "Digital architecture as a challenge for design pedagogy: theory, knowledge, models and medium," *Design studies*, vol. 29, no. 2, pp. 99–120, 2008. [Online]. Available: https://doi.org/10.1016/j.destud.2007.12.003

[28] M. A. Gallas, K. Jacquot, S. Janca, and F. Delvaux, "Parametric modeling: An advanced design process for architectural education," *in eCAADe 2015, Vienne, Austria, 2015, September*, 2015. [Online]. Available: https://doi.org/10.52842/conf.ecaade.2015.2.149

[29] S. Ceylan, "Using virtual reality to improve visual recognition skills of first year architecture students: A comparative study," *Scitepress: in Proceedings of the 12th International Conference on Computer Supported Education (CSEDU 2020)*, vol. 2, pp. 54–63, 2020. [Online]. Available: https://doi.org/10.5220/0009346800540063

How to cite this article:
Sarraa Younis and Dhuha A. Al-kazzaz. (2025). 'The knowledge content of digital design subject in architecture schools', Al-Qadisiyah Journal for Engineering Sciences, 18(3), pp. 249-256. https://doi.org/10.30772/qjes.2023.143373.1031