International Journal of Architectural Engineering & Urban Planning, Volume 33, Number 4, 2023
DOI: 10.22068/ijaup.648

Research Paper

Educational Structure in Digital Architecture; Challenges and Opportunities

Mehran Kheirollahi *, Sara Safarnezhad

Department of Architecture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

Received: March 2021, **Revised:** December 2023, **Accepted:** December 2023, **Publish Online:** December 2023

Abstract
The failure to adapt existing architectural education models to the evolving cultural and technological landscape of the digital age, coupled with the rapid advancements in computer programs within the architectural profession, has underscored the imperative of establishing a proficient framework for architecture education that aligns with the demands of the contemporary architectural landscape. In response to this exigency, architectural design concepts have emerged as instrumental tools in the instructional paradigm of digital architecture, mirroring the crystallization of modernism during the Bauhaus period—an era marked by significant shifts in theoretical and design perspectives. The principal objective of the current investigation is to comprehend the educational framework of digital architecture with the intent of bridging the existing gap between architectural education and professional practice. The methodology employed for data acquisition in this study encompasses comprehensive library research and an examination of pertinent documents. The convergence of architecture and digital education has introduced a novel trajectory for the advancement of pedagogical practices within the discipline of architecture. However, the integration of laboratory activities and technological components in practical training remains sluggish, necessitating responsiveness to societal demands, increased financial allocation to educational infrastructure, and the mobilization of teaching resources to facilitate widespread adoption and sustained advancement. The adoption of a research project-oriented approach to teaching has proven instrumental in achieving the objectives of motivating students to contemplate various facets of the nexus between technology and the environment.

Keywords: *Digital architecture, Educational structure, Collaboration-community response-social stimulation.*

1. INTRODUCTION

The pervasive influence of digitalization is widely recognized as a driving force reshaping the hierarchical dynamics within education, particularly in the realms of design and implementation. Contemporary architectural design, underscored by significant manifestations within the virtual realm, image architecture, and digital simulation, necessitates a corresponding evolution in architectural education to effectively respond to these transformative shifts (refer to Figure 1). The incremental revelation of digitalization's footprint in architecture education is imperative, given the dynamic nature of information technology (IT) and its cascading effects across diverse industries and emerging fields of study.

The progressive integration of digital technologies into architectural education has been instrumental in enhancing efficiency within engineering disciplines over time (Wangler et al. 2019). This, in turn, contributes to a more tangible realization of sustainability within society (Abdelhameed 2018). The transformative impact of digitization extends beyond the educational domain, fundamentally altering societal interactions and engaging various facets of life in unique ways, thereby reshaping the landscape of architectural specialization (Andia, 2002; Soliman et al., 2019). The evolution of teaching methodologies and a deeper comprehension of architecture are undeniably intertwined with the process of digitization (Abdelmohsen 2017).

* *Corresponding author: dr.mehrankheirollahi@gmail.com*

The once-prevailing skepticism and criticism directed towards digital education have significantly diminished (Guney 2015; Henri 2003). Furthermore, there is a growing imperative for interdisciplinary research within the field of architecture in response to the transformative impact of digitization. Emerging digital information technologies, including the Internet of Things (IoT), big data, blockchain, artificial intelligence (AI), and digital manufacturing, are discreetly reshaping the traditional contours of the industry, marking a departure from established norms.

The dynamic evolution of design knowledge within the theoretical and practical domains of architecture necessitates corresponding adaptations in education. Examining historical precedents, the Bauhaus stands as an exemplary model; during the era of industrialization, it embraced problem-related learning, juxtaposing concepts and materials to create an empirical legacy in architectural education. Similarly, a contemporary educational framework could draw inspiration from such dichotomies, wherein digital media becomes the catalyst for novel integrations between architectural theory and design theory.

Prompted by these considerations, a critical inquiry arises: how does a digital studio distinguish itself from a conventional paper-based studio? Does the inherent nature of digital design exert a transformative influence on the design processes to an extent that necessitates the incorporation of new conceptual frameworks and structures within studio training templates? Can we assert that digital architecture has reached a stage where emerging conceptual terms can be precisely defined? These questions encapsulate the challenges inherent in devising a training framework tailored to the demands of digital design education.

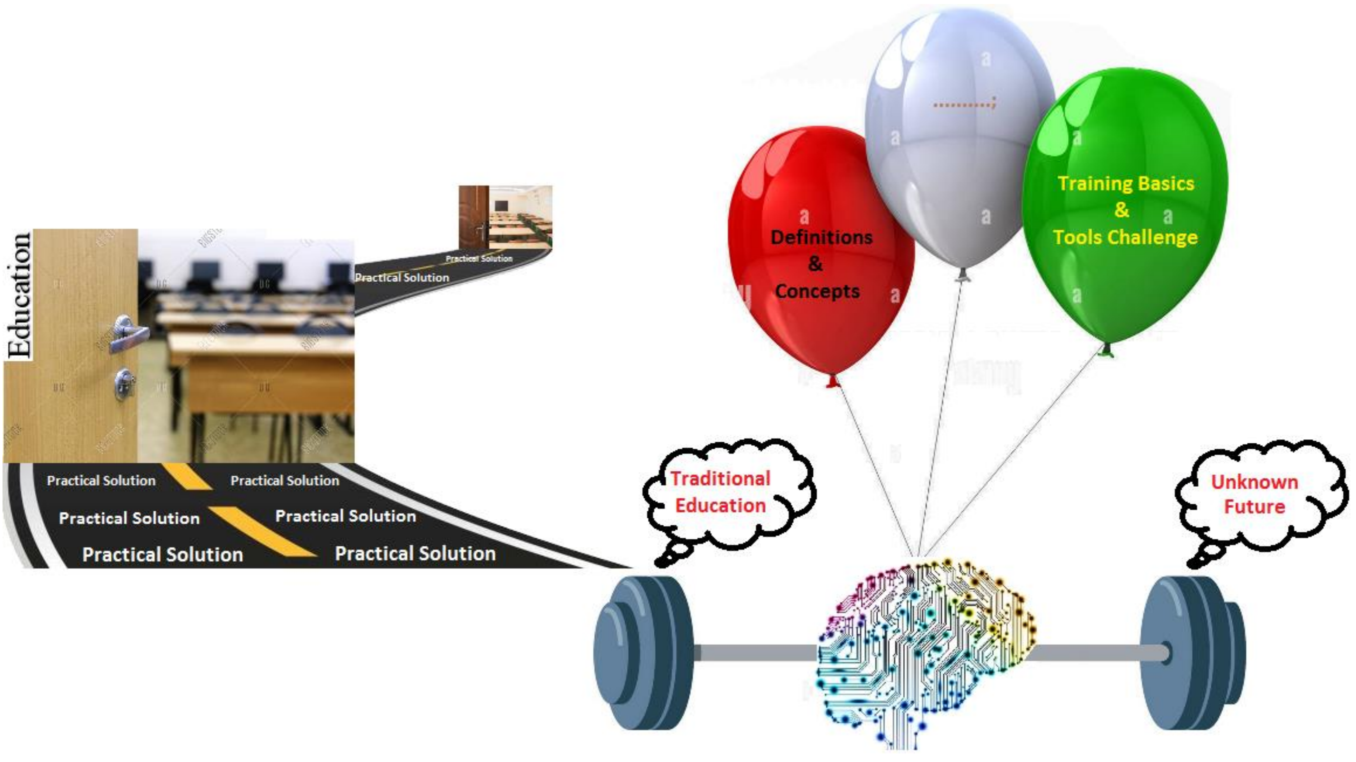

Fig 1. Significance of the study [Authors]

2. RESEARCH METHOD

The nature of the conducted case study is inherently qualitative, aligning with the overarching objective of crystallizing educational methods within the realm of digital architecture. In accordance with the purpose, this study is classified as developmental research (Richey 2005). The elucidation of the problem framework is derived from the inquiries posed at the conclusion of the initial section. To systematically identify limitations, a comprehensive examination within the theoretical domain is undertaken in section three.

The primary objective of the current investigation, as expounded in section four, is to discern the educational structure of digital architecture with the explicit aim of narrowing the existing gap between architecture education and the professional practice of architecture. To achieve this objective, an experimental design studio, titled "Design as Research: Exploring the Concepts of Digital Architecture," is proposed to delineate a framework for the training of digital architects. A series of research programs conducted within this studio serve to exemplify and substantiate this proposed framework (refer to Figure 2). It is noteworthy that the case study results stemming from the design studio, coupled with an extensive review of related literature, collectively constitute the research methodology, transcending confinement to a specific paper segment.

Importantly, theorists and evaluators actively participate in the investigations carried out within the design studio. The identification and announcement of all pertinent research variables are explicated in section five, while the subsequent section, section six, is dedicated to the meticulous analysis of the amassed data.

Fig 2. Concepts of problem solving

3. THEORETICAL AREA

3.1. Digital Architecture Highlights

Figure 3 presents a schematic representation of key theoretical points in digital architecture. The delineation of these points encompasses:

Impact of Conceptual Content: Beyond the mere evolution of the design environment, the new design paradigm has ushered in a proliferation of novel concepts. These include distinctions such as continuous versus discrete, complex versus hierarchical, topology versus typology, matter versus space, structure versus form, and formation processes versus representation, among others. Lynn (2002) characterizes this shift in spatial, formal, and hybrid terms as postmodern. Notably, wherever the terms "form," "space," "design," "order," or "structure" converge, it signifies a manifestation within the realm of modernist discourse [Forty 2000].

Beyond the Representational Shape Design: Any innovative approach in a new educational context that aspires to cultivate novel forms of digital design thinking must inherently transcend the confines of the formal representation syndrome. This entails moving beyond conventional formal language and aesthetics, delving into the intricacies of hybrid collage.

Materials: An additional objective of contemporary digital education is the redefinition of "materials." The conventional interpretation of sketches, characterized by a step-by-step visual exploration of form, stands in contrast to the digital approach to "materials." Digital design introduces a distinctive design ontology that fundamentally departs from traditional notions. Reiser and Umemoto (2006) propose a hypothesis in this regard, advocating for the abandonment of fundamental perceptions that posit matter as amorphous and subject to the regulation of transcendent geometry. Instead, their assertion posits that matter possesses an inherent capacity for organization.

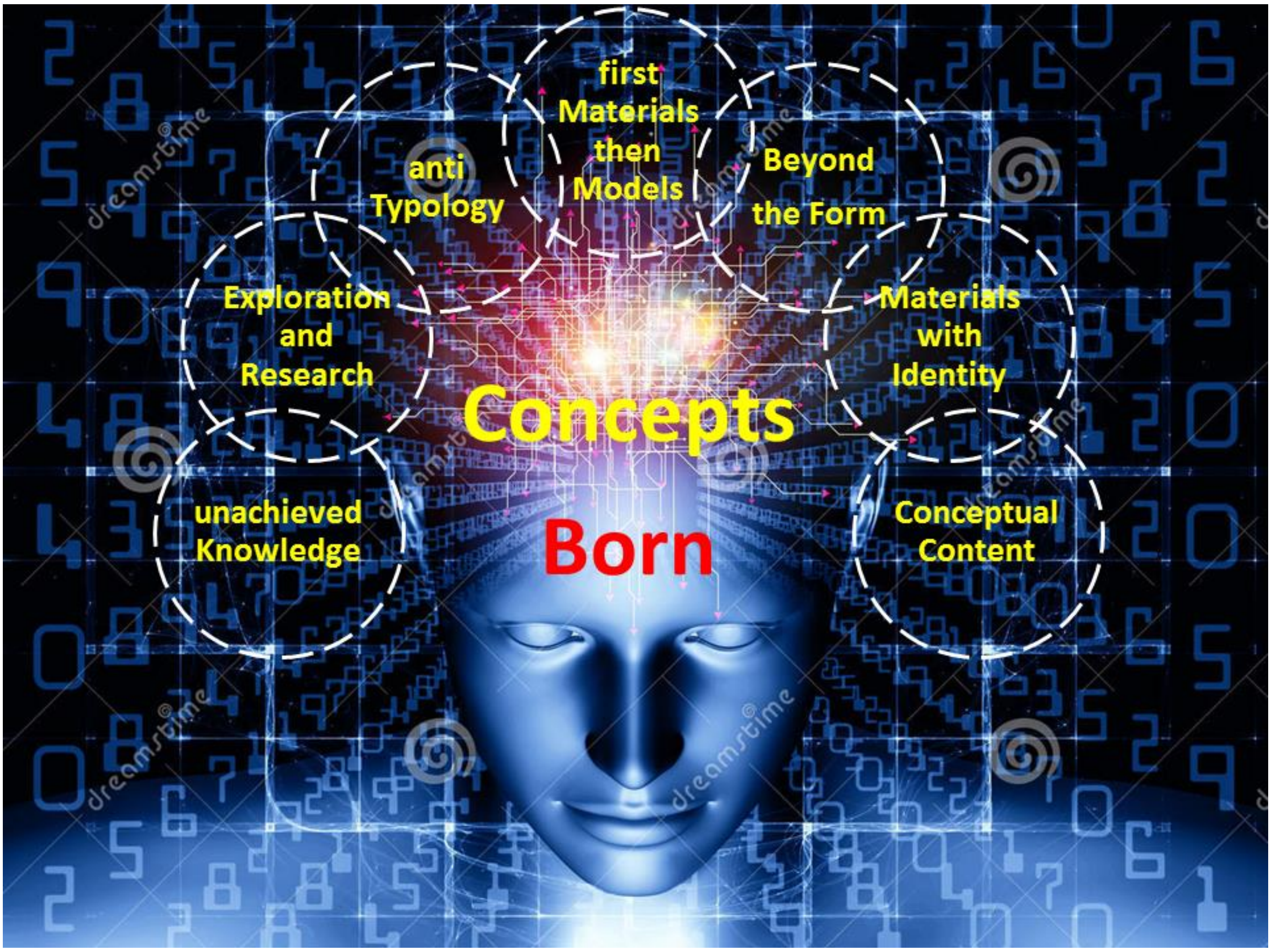

Fig 3. Concepts born in digital architecture [Authors]

Educational Concepts: The design studio typically relies on established knowledge and typology in architectural education, progressing through ideation, schematic design, and design development while theoretically interpreting the program, site, and conditions. However, with the introduction of digital design, featuring new conceptualizations and methods, there is a profound impact on the content and execution of the design studio. How the new environment and knowledge base affect the content and performance of the design studio is a key question to address.

Transforming the Definition of Design Issues Typology: Colquhoun (1989) asserts that typology, being one of the fundamental principles in modern architectural education, holds the capacity to convey meaning. However, digital design processes offer a distinct orientation for exploration and design creativity. Definitions of digital models, such as "animation" or "parametric design," can serve as initial reference points for delving into design. These orientations explicitly adopt an anti-typological stance.

Design Process Conversion: A novel conceptual vocabulary may necessitate distinct stages of exploration, a shift achievable by liberating students from traditional design studio expectations. Instead of adhering to a conventional sequence involving the analysis of a specific site, defining applications, conceptual design, architectural space creation, visual display, etc., an educational approach that transcends this sequence is advocated. The educational process need not strictly adhere to a "project-oriented" paradigm in the conventional sense. Assuming that design is an exploratory and research-based endeavor, the absence of a predefined program or site at the outset marks a departure from traditional approaches. Education, in this context, may adopt a "model-driven" perspective. This transformative shift involves initiating the design process with a focus on "material exploration first" when examining digital models and processes, representing a fundamental change in design logic. In this paradigm, theory is articulated as a method, and the method itself evolves into a model of the design process within the studio.

Digital Environment and Design Process: The primary objective of the studio is to elucidate the connection between concepts in digital models and digital design processes. The propelling forces of digital design encompass formation, production, and function. The integration of these three processes with a consideration for new materials constitutes a central theme in design research. The proposed sequence for digital architectural design methods advocates starting with materials and subsequently selecting a digital design model. Given the orientation toward exploration and research, each student can be allocated a digital task that incorporates concepts and methods tailored to their individual interests and talents.

3.2. Digital Architecture and the New Learning Challenge

We are encountering novel perspectives in elucidating the evaluative aspects of design, emphasizing functional and productive considerations. Beyond Schön's characterization of visual reasoning as a "dialogue with the problem's material" and the "return of dialogue" from visual images, the digital design of "materials" has introduced a fresh understanding of design that may underscore the distinctive nature of digital design thinking. Architectural thinking, aligning with this distinction, has been presented as non-typological and uncertain. The incorporation of techniques like parametric formation has opened up new realms for the exploration of design. These models exemplify the escalating influence of digital design media as an intermediary between content and skill.

Fundamental concepts in design theory, such as representation and typology, along with principles of visual literacy, have undergone a transformation in design education. Instead, concepts like morphology, outcome, and performance-based design, as well as materialization and production, take precedence. Digital design is interpreted through four paradigms: formation, production, performance, and performance-based production (refer to Figure 4).

Given the increasing demand for digital design media expertise, including knowledge of various software types, proficiency in scripting languages, and the manipulation and maintenance of complex data models, there arises a need to train a new generation of digital design professionals. The designer's proficiency in customizing digital design media reflects the necessity for specialized knowledge in this domain. Consequently, the notion of digital experts as advanced designers of digital systems aptly describes the contemporary situation.

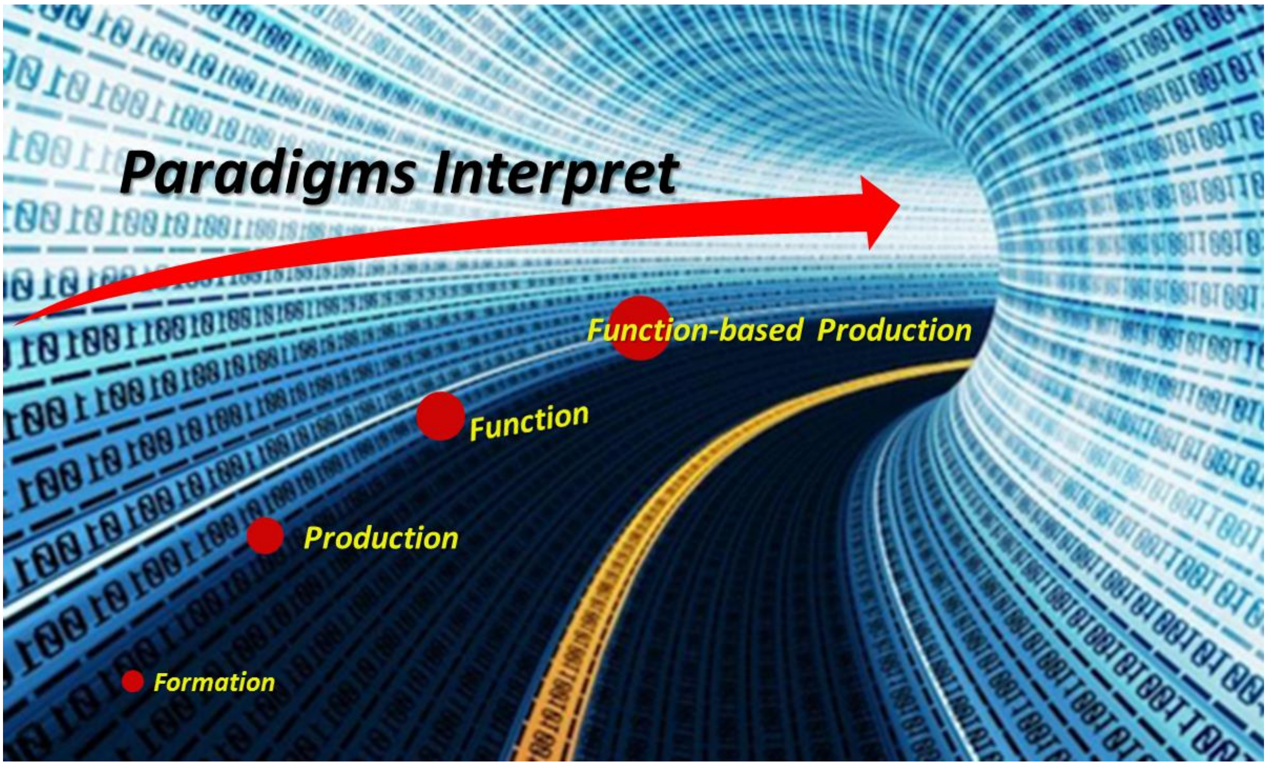

Fig 4. Interpretive paradigms in digital design [Authors]

4. TECHNOLOGY IN EDUCATION

4.1. Evolution of Digital Architecture Training

While digital education in architecture has evolved over a span of less than half a century, it has played a pivotal role in enhancing the structure of architecture and practical production through diverse digital knowledge and technologies. The progression can be delineated into approximately four stages, spanning from the inception of Computer-Aided Design (CAD) to Computer-Aided Manufacturing (CAM).

In the early stages (1970-1990), the use of information technology was predominantly influenced at a technical level (Andia 2002). This era witnessed a positive shift in thinking, evident in the transformative impact of computer architecture design systems on practical implementation and design education. During the rapid development phase (1990-2000), global digital education and information sharing saw a substantial increase, aided by technological support for communication and networking (Fonseca et al. 2017). However, during this period, the concepts were not fully realized, and practical communication remained a challenge.

In the successful transition phase (2000-2010), digital technology became firmly established in forthcoming architecture education, witnessing increased integration of digital technology, practical architectural activities, widespread computer usage, and the incorporation of programming in design procedures as part of digital courses (Schenk 2005). Yet, notable researchers in digital education during this time did not fully encapsulate the core essence of digitalization.

During its heyday (2010-), a significant leap occurred in digital education, marked by manufacturing success. Various technologies emerged rapidly in real-life applications and future research [Valls et al. 2018]. Guided by digital technology, education moved beyond traditional stages (Phocas et al. 2011), with most digital technologies being integrated into curriculum schedules. The utilization of new technologies, particularly in building information models and analyzing physical links, became a critical focal point in architectural education.

Figure 5 illustrates the trajectory of digital technology in architecture education, progressing from an early-stage independent assistance tool to mutual conceptual design, representation of virtual reality, and interdisciplinary research. Digital architecture continually expands its concept in practice, fundamentally transforming the entire organizational structure of architectural education. Simultaneously, architecture education is transitioning to a modern dynamic space, characterized by exploding information, interaction, and coexisting challenges.

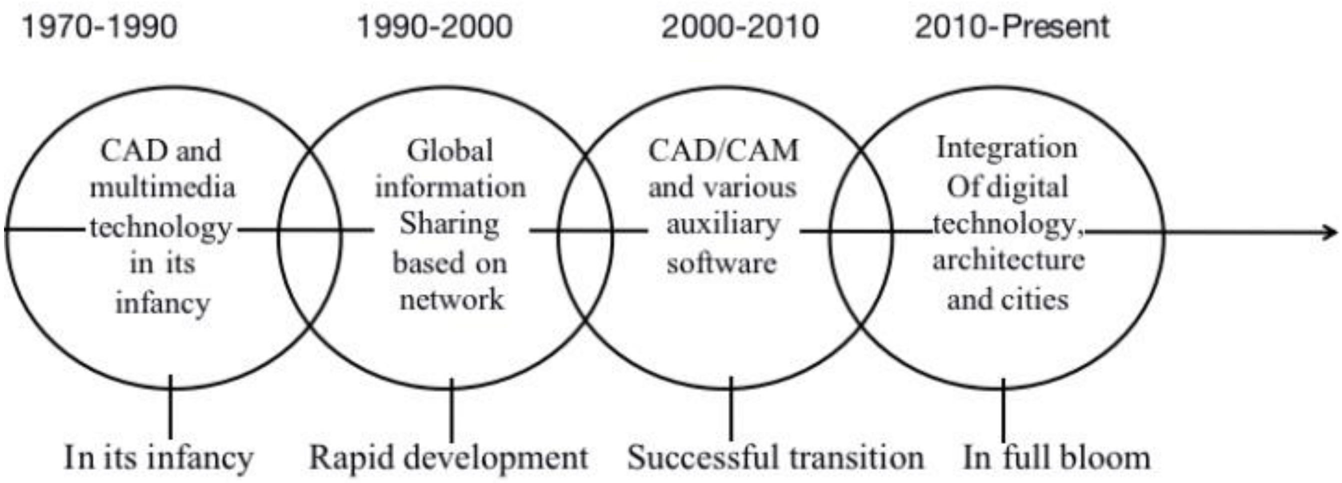

Fig 5. Development of digital architecture [Liu & Wang 2020]

4.2. Changing Digital Architecture Training

Recent research in digital manufacturing underscores the substantial utilization of digital technology, presenting a considerable potential to fortify the manufacturing industry (Craveiroa et al. 2019). This trend is anticipated to significantly reshape the educational landscape of architecture in the future. The pervasive influence of the information society has led to the integration of digital information technology into design research within digital education programs. These programs aim to chart new directions for digital education, exploring the relevance of digital technology in the forthcoming education landscape of architecture.

The engagement of digital research in architecture serves as a gateway to interdisciplinary exploration. A notable advantage of digital education in architecture lies in its comprehensive harnessing of digital manufacturing potential. This approach fosters the establishment of a robust interdisciplinary environment that seamlessly integrates various disciplines, including civil engineering, architecture, computer science, materials science, and robotics technology. Digital education in architecture encompasses the creation, processing, dissemination, and application of knowledge, fostering mutual enhancement and generating a powerful collective impact.

The pervasive integration of digital technology is poised to revolutionize the practical education and technological landscape within the field of architecture. The synthesis of architecture, physical manufacturing, and digital technology in the future is expected to undergo a redefinition, paving the way for the emergence of a new design paradigm.

5. DIGITAL ARCHITECTURE EDUCATION TOPICS

5.1. 3D Organizational Structure of Research, Learning and Production

As we transition into the 21st century, the application of digital technology in architectural education has been explored, leveraging research strengths and laboratory achievements. This exploration involves presenting research ideas and trends in the realm of digital education in architecture. In contrast to the prevalent "plug-in" mode for digital architecture found in many institutions, which lacks a systematic educational framework, a diverse array of educational resources, including digital technology and machine intelligence, has prompted a fundamental shift in the thinking about digital architecture.

Digital education in architecture has evolved to encompass a structured framework of "training activities -laboratory research- innovative production." Within technology institutes of architecture, as a subset of the School of Architecture, specific places have emerged as leading platforms for the education and maturation of digital architecture. These platforms have been established through extensive inquiry and practical action, consisting of laboratories organized into four segments: digital architecture, digital architecture and manufacturing, digital building technologies, and architectural information. Each segment is overseen by expert professors, and the teaching outcomes from these laboratories are transformed into technical outputs.

In the next step, the analysis will concentrate on three main strands, comprising digital architecture courses, laboratory studies, and the resulting outcomes.

5.2. The Main Research Path in Digital Architecture

Digital education in architecture is characterized by a well-defined goal, marked by a clear research path and robust connections between research groups. This coherence is so pronounced that it fosters the cultivation of international talents through the creative integration of industry and education. The initiation of digital courses at the undergraduate level is complemented by the study of digital architecture theory, culminating in the establishment of a comprehensive educational system.

Advanced students, guided by their proficiency in digital concepts, progressively transition through software application and experimental operations. This sequential progression contributes to an elevated level of information and the quantification of urban data.

Digital education in architecture encompasses four foundational pillars: digital architecture, digital architecture and manufacturing, digital building technologies, and information architecture (refer to Figure 6). Each component serves a distinct purpose:

The objective of digital architecture, emphasizing the reciprocal relationship between technology and humanity, is to expand educational content and address a variety of issues stemming from urbanization through digital solutions. To achieve this goal, the lab has meticulously developed a detailed curriculum with specific content and examination strategies, guiding students in the following directions: Firstly, the curriculum aims to tackle challenges associated with digital technology in the urban regeneration process. Secondly, it endeavors to foster a profound understanding of the working principles of the digital realm, encouraging exploration and in-depth research in various facets of digital architecture.

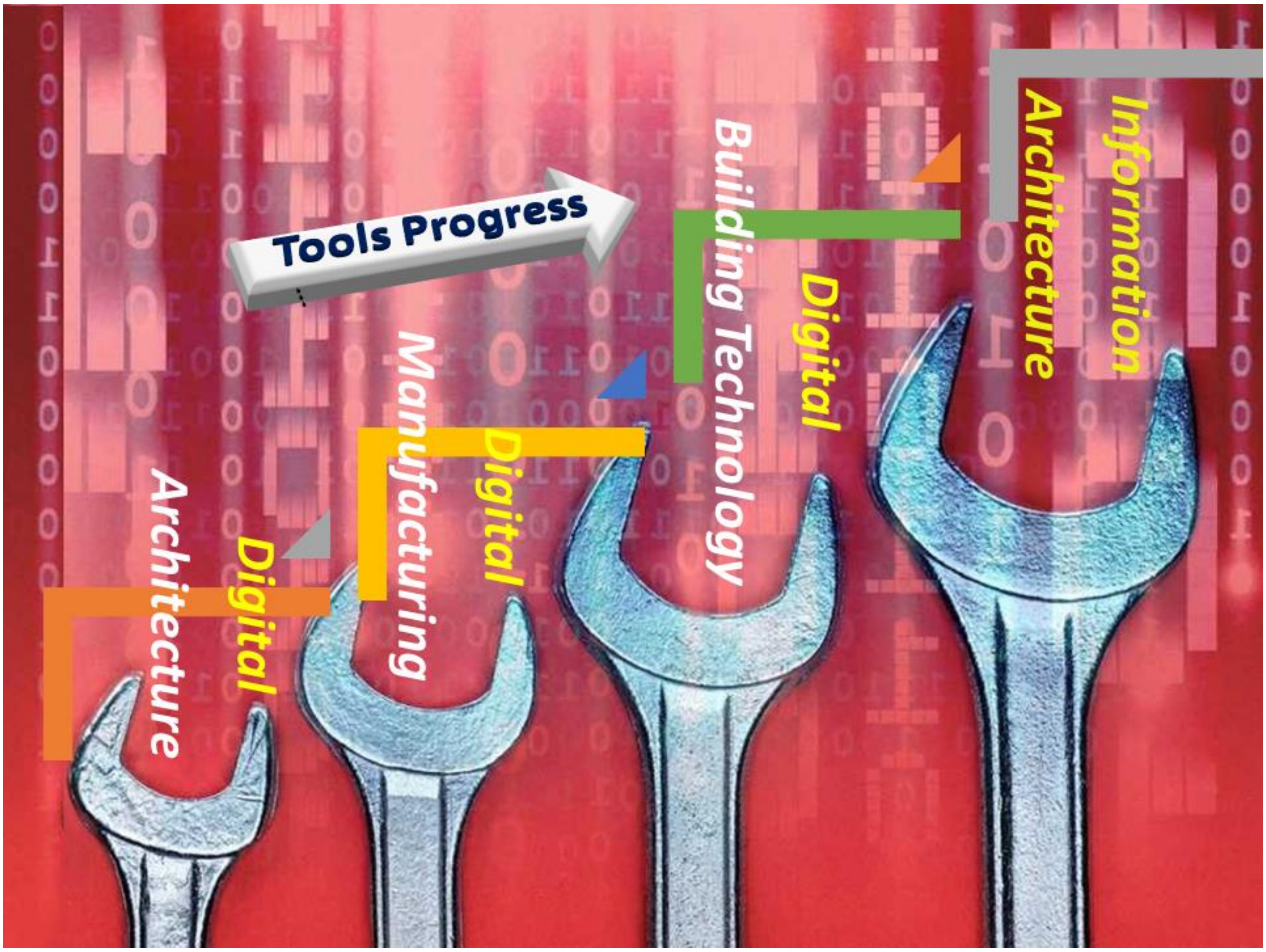

Fig 6. Digital tools from buildings to cities [Authors]

In this context, instructional design is no longer a mere demonstration; the primary task is to empower students to cultivate skills in parametric design using programming languages and generate diverse solutions. Professors from diverse regions and disciplines consistently contribute their expertise to the curriculum, ensuring a global perspective in basic education and fostering a solid understanding for future research in digital manufacturing technologies.

Digital building technologies are designed to explore emerging technologies, leveraging the capabilities of advanced computational design systems and the integration of digital manufacturing with novel materials. According to Benjamin Dillenburger, a distinguished professor, digital technology is poised to become the primary driving force behind the development of new materials and manufacturing methods. This convergence challenges traditional architectural concepts, aiming to achieve high efficiency and low-cost manufacturing strategies in a short time frame. Additive technologies, such as 3D printing, are particularly promising in the manufacturing realm.

The approach involves the formulation of intricate design solutions aimed at enhancing the qualitative aspects of the manufacturing process. The transformation of conceptual designs into manufacturable entities is a key objective, highlighting the shift toward more efficient and technologically advanced building practices in the digital era.

Architecture and Digital Manufacturing: In response to the advancements in digital smart building, the laboratory focuses on three key training areas: computer design, robot manufacturing, and construction systems. The training tasks are designed to facilitate the learning process in digital construction, integrating material performance and aesthetic quality. Through these tasks, students develop skills in constructing components digitally.

The emphasis is on the ability to digitally construct non-standard building components. Comprehensive exercises and research training methods are employed, enabling the utilization of advanced digital manufacturing techniques to understand and explore the intricate relationship between material and design.

Information Architecture: Sustainable urban evolution stands as a crucial research trajectory for the cities of the future. With the intensification of global urbanization, cities have become the primary habitats for a majority of people, emphasizing the significance of thoughtfully planned urban settlements. Professor Gerhard Schmitt, a notable figure in information architecture, espouses the view of a two-way relationship between cities and residents (Schmitt 2015). His research delves into the impact of digitization and information on the future development of urban areas.

In the educational realm, students engage in mastering digital visualization tools and processing methods using digital data and information. Through the simulation of urban information, a platform is created to model future urban interactions, contributing to the effective management of quality in urban social spaces. The integration of information architecture takes digital architecture from the manufacturing level to the city level. This transformation facilitates mutual communication between cities and residents, ushering in a new era of interactive and informed urban development.

Features of Digital Architecture Training

There is a need for spinal cord which makes the structure of digital education (figure 7):

Interdisciplinary Public Education System: Incorporating interdisciplinary science is a contemporary approach in higher education aimed at addressing the evolving needs of society. Design education, in particular, should align with societal needs and overcome the traditional separation of sciences, fostering a more integrated and holistic understanding of disciplines. The interdisciplinary mindset, a fundamental element of digital education in architecture, places a strong emphasis on cultivating students' practical design abilities and understanding, progressively influencing public education.

A series of computer-aided architecture design courses are introduced as part of the curriculum, focusing on the integration of theory into practice and bridging the gap between abstract concepts and real-world applications. Ludger Hovestadt, a course instructor, emphasizes the current necessity of digital architecture lying in the utilization of technological advances from various specialties in the manufacturing industry, rather than solely focusing on virtual reality technology.

Students' cognitive knowledge is a fusion of architecture, computer science, psychology, sociology, mechanics, and robotics. Emerging digital technologies such as the Internet of Things, machine intelligence, and big data are introduced as new educational concepts to assist students in identifying and addressing urbanization challenges. General education components, such as seminars and exercises with dynamic and complementary aspects, prove effective in expanding students' insights and skills. In summary, the interdisciplinary education system in digital architecture is rooted in the integration of multidisciplinary knowledge and expertise.

Fig 7. Graphical structure of education formation in digital architecture [Authors]

Online and Offline Teaching Model: Theoretical and practical design training often faces limitations imposed by the availability of sites and equipment (Rodriguez et al. 2018), impacting the functional contributions students can make (Bergström 2014). To address this challenge, future courses on urban topics will adopt a co-teaching method, actively engaging in discussions on urban environmental issues. The virtual design studio's online courses, spanning the domains of future cities, livable cities, smart cities, and responsive cities, simulate city activities under the metaphor of the metabolism of a living organism. These courses incorporate interactive discussions to facilitate interdisciplinary knowledge exchange, assignments, exams, and e-learning, enabling students to investigate urban issues based on data.

In offline education, digital information processing is emphasized, exploring bio-urban problems and employing effective communication methods online through courses such as "Data Mining - Information Architecture - Digital Analog - Urban Response." Simultaneously, under the guidance of professors, field research activities, including data collection and processing, are conducted. The culmination of these efforts involves engaging experts in urban planning and design to further enrich the learning experience.

The interactive learning facilitated by the studio can serve various purposes, including assessment, content integration, and problem-solving. Both online and offline teaching methods are network-based, characterized by data visualization and the creation of diverse educational approaches. This approach eliminates limitations on student participation, fostering motivation for learning. The combination of independent online learning, guided offline learning, teamwork, and the mitigation of the weaknesses of a singular approach can be achieved through innovative experimental methods, ensuring the adaptability of the entire teaching process to future themes and diversified development.

Moreover, education in architecture is time-variable, and to enhance individual skills, a series of digital architecture training programs focusing on construction, with additional workshops and laboratories, are offered at different educational levels. The primary distinction among these courses lies in the depth and breadth of learning, catering to diverse needs and skill levels.

Enhancing the quality of education through interactive teaching of digital production technologies by academics and industrialists. Second, Increasing digital literacy to fully utilize the practical potential of digital programs. Improving teamwork skills to implement 1:1 conceptual designs using advanced manufacturing equipment.

Students enroll in practical digital manufacturing courses, acquiring proficiency in digital design and assembly processes to enhance their career prospects. Addressing social needs is imperative to bridge the gap between knowledge and practical application in the realm of digital architecture, fostering creativity and management skills in students. Public education initiatives play a crucial role in promoting digital manufacturing within the construction industry.

5.3. Preliminary Laboratory Research

The laboratory facilitates the development of students' abilities in digital education in architecture by combining technical knowledge with hands-on experience.

Robotics laboratory: The linkage between design and digital manufacturing is facilitated through the use of computers and robots. Students gain familiarity with automated manufacturing processes, transform conceptual works into physical outputs through 3D printing at a 1:1 scale, and actively participate in exhibitions and festivals. Additionally, they collaborate with specialists from other disciplines within an interdisciplinary team.

Future Cities Laboratory: The laboratory was established with the primary objective of showcasing the role of technology in digital education and presenting interdisciplinary technological products within the realm of architecture. This exhibition highlights the profound impact of digitalization on both design processes and energy consumption. By eliminating boundaries between different disciplines, the "digital chain" seamlessly integrates design with production, fostering a commitment to sustainable development. The exhibition focuses on generating themes and exploring strategies to enhance the urban environment.

In this collaborative endeavor, digital manufacturing artisans work alongside professors, co-teaching subjects such as Computer Design, Robotics, and Structure of Materials. Among the research topics explored within the laboratory, the construction of high-rise modular buildings stands out. This laboratory serves as a catalyst for rapid changes and increased diversity in urban construction (Willmann et al. 2015). The dissemination of results and discussions takes place through seminars, exhibitions, and articles, providing a platform for sharing and analyzing the outcomes of the research.

5.4. The Result of Research and Practical Exercises

Early-stage research serves as the foundation of technology and a catalyst for innovation-driven development. While accomplishments and scientific articles have traditionally been crucial indicators of educational excellence in colleges and universities, there is a growing recognition of the importance of technology transfer. Emphasizing the value of technology transfer is essential to cultivate an innovative education ecosystem from various perspectives. The direct translation of research findings and their prompt integration into the industry has emerged as a primary objective in education. This goal holds particular significance in the context of the conventional branch of architecture within the university setting. The realm of digital construction provides a platform for synergies across various achievements, contributing to the establishment of a robust ecosystem for digital education in architecture.

Focus on Transformation in Educational and Research Achievements: In the graduation phase, the amalgamation of articles, practical research, and the transfer of achievements serve as a significant manifestation of faculty teaching outcomes. This approach enables students to seamlessly integrate their work with laboratory research results and collaborate with local construction companies. Construction processes, executed through a series of digital procedures that transform concepts into reality, prove invaluable for teaching innovation skills, promoting student collaboration, and aiding technology companies in updating their products.

Within the university, there is a commitment to supporting pragmatic basic research, with professors and students assuming pivotal roles in fostering innovation and entrepreneurship. A pioneering program has been instituted to empower professors and students to take initiative, breathe life into various facets such as technology, capital, social action, and value orientation, and drive research results to the market. Consequently, the university actively engages in collaborations with research and development institutes. This collaborative effort results in the translation of research into practical applications, leading to the emergence of numerous start-ups with new industrial potential. Thus, the primary goal of teaching digital architecture at the university is successfully realized.

Innovation and Technology Park: The Innovation and Technology Park stands as a crucial hub for research, development, and technology transfer, comprising innovative science and technology companies along with scientific research institutes. Together, they collaboratively offer a service platform supporting innovation among university students and fostering entrepreneurship. The university plays a pivotal role by providing a comprehensive entrepreneurship guide and conducting thorough assessments. Annually, hundreds of international inventions are patented through this initiative, making a substantial contribution to the enhancement of national capability and innovation. The Innovation and Technology Park has emerged as a transformative avenue for translating the educational and research accomplishments of the university into tangible outcomes, serving as a vital platform for synergizing the university, industry, and research sectors.

Strengthening Cooperation in Education, Research, and Production: Companies have entered into cooperation agreements and strategic alliances with colleges and universities, leading to the establishment of joint research and development laboratories. In these collaborations, the laboratory transcends its traditional role as a mere experimental unit and, instead, harnesses innovation as a driving force to integrate training, practice, design, and construction within the same space.

6. Do's and Don'ts

Enlightenment for architecture education: The digital economy, acting as an effect, and the digitization of production methods, serving as a cause, can be likened to two wings propelling society through the valleys of backwardness. The digital economy serves as a crucial platform for national strategic decisions, ushering in leaps in quality and societal transformation. However, the factors of investment and innovation in the construction industry are still in their infancy, necessitating the continuous updating of education in the field of digital architecture for their maturation. Looking ahead, the national policy for training digital personnel will encompass the following aspects:

Creating an infrastructure for flexible digital education in architecture with the help of digital technology to respond to the needs of society: Flexibility is attained through a combination of online and offline courses, catering to diverse learning abilities and, consequently, fostering the power of collaboration among students. However, aligning the design studio with the policies of equipment digitalization and educational models requires thoughtful consideration.

Promoting collaboration and research in response to industrial demand: In the realm of digital architecture, education is characterized as interdisciplinary research, with tools serving the social development of students. Multidisciplinary cooperation in this context involves the integration of "science and engineering," "engineering and engineering," and "art and engineering" into the domain of professional education.

Making social demands on students and introducing multilateral cooperation algorithms: Hence, "education, research, and production" serves both an academic function and addresses a societal need. Education, viewed as a social responsibility, demands collaborative efforts from universities, research institutes, companies, and governments. The more profound the engagement with digital architecture, the greater the potential for social development. Consequently, there is a necessity for an industrial training platform to facilitate this ongoing communication.

Collaboration: While highlighting the positive aspects of cooperation, it is crucial to acknowledge the drawbacks as well. In a group setting with diverse individuals, each contributing valuable ideas, there is potential for thoughtful learning (Figure 8). However, striking a balance between the desire for heightened group collaboration and the importance of fostering individual student growth is paramount. Observations of group dynamics reveal instances where computer-related tasks are predominantly handled by a technically skilled student, leaving others with limited exposure to the same learning experience. Addressing and improving this imbalance is imperative.

Teaching and research: There must be an interactive relationship between research and education. An intriguing aspect of this approach involves incorporating an ongoing research project that delves into the intricate connections among people, technology, and space. The teaching approach intentionally blurs the line between research and instruction, urging students to actively engage in research and seek their own interpretations. However, it is essential to acknowledge that education and research may demand different spaces and do not inherently serve to reinforce each other. Research entails the discovery or creation of new knowledge, while teaching involves the transmission of direct perception (Rowland, S., 2006). The varied objectives of education may conflict with the research program and its time-budget constraints. Although it is argued that research can and should inform teaching, understanding the role of discovery in learning—examining an evolving context at the forefront of research—is crucial. Consequently, teaching and learning can complement and enhance research. As Rowland (2006) aptly stated, "If discovery is an important aspect of learning, as it is in research, then it can link education and research: the space of discovery can be one of the needs of each."

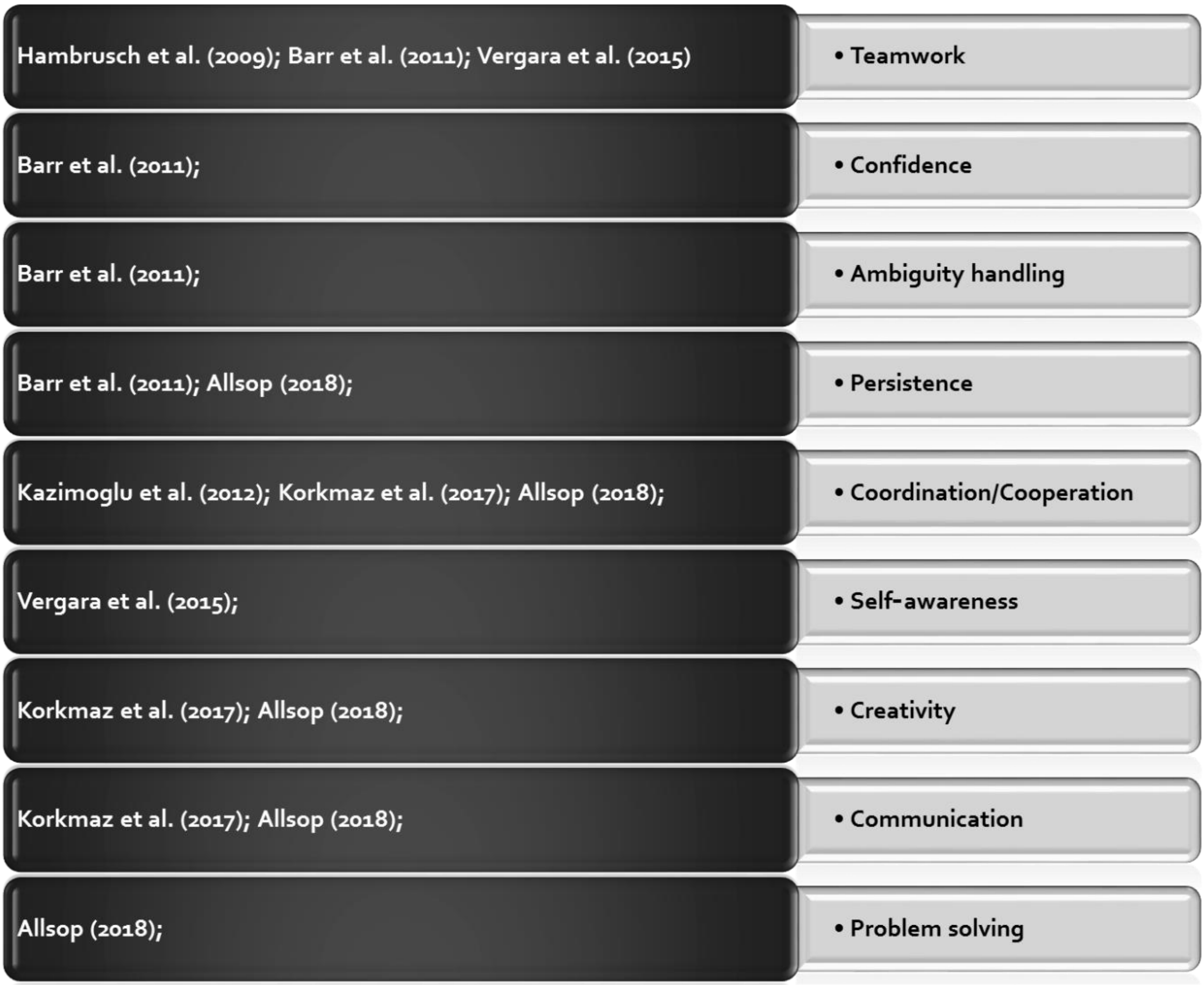

Fig 8. Individual capabilities in teamwork

7. CONCLUSION

"Architects in the post-digital age are coding, and robots are building our buildings," remarked Hopkins. Traditional architecture still lags behind in integrating education and practice, requiring increased social attention, structural investment, and training forces for advancement.

The work presented in this article raises the question of the extent to which research can "inform" education. Students could witness their professors navigating a learning curve due to new technology, challenging the assumption that instructors solely act as custodians and distributors of knowledge.

Another noteworthy issue highlighted during the project pertains to collaboration and the creation of a shared learning environment with shared responsibility, which may have both advantages and disadvantages. A major challenge in curriculum design is ensuring that the three domains—knowledge, action, and self—are adequately represented and, most importantly, effectively integrated (Barnett et al., 2001).

How can we optimize the learning experience? Does our curriculum effectively function? How should we assess? These questions, central to creating an inspiring learning environment for designers and architects in the dynamic digital age (Figure 9), have been addressed through research and in-depth reflection in the present work.

A key takeaway is encapsulated in a digital message: To achieve digitalization, there is a need for socialization preceding technicization. In other words, human sciences precede technical sciences and the application of technology; a crucial aspect that has held us back from …

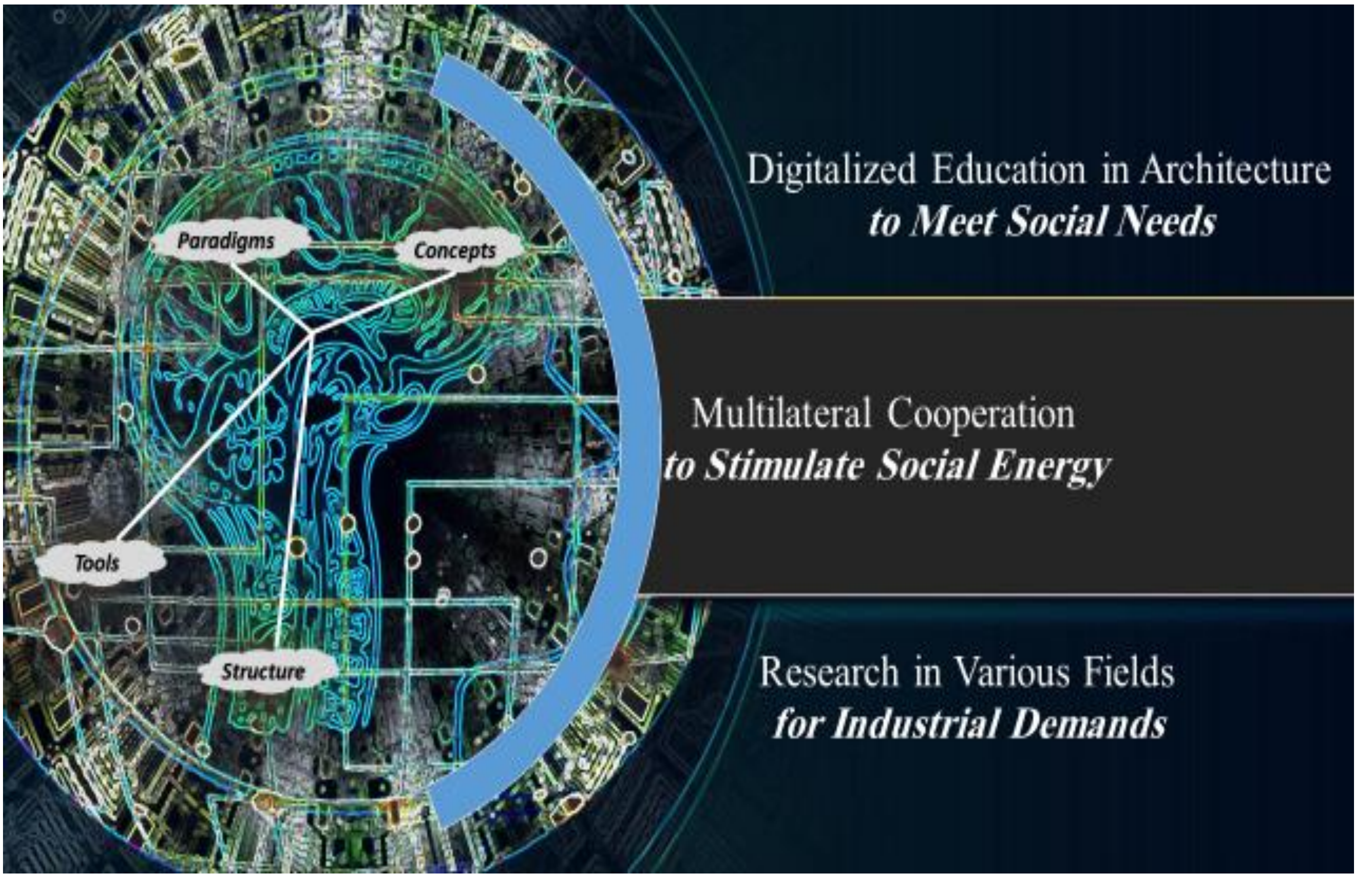

Fig 9. Practical achievements of putting together the requirements for building an educational system in digital architecture. [Authors]

8. ENVISIONED FUTURE STEPS

The approach outlined in this research, along with its merits and drawbacks, marks a modest stride towards the digitization of education. However, a crucial, overlooked aspect is the need for investment—a responsibility that squarely falls on the shoulders of governments. The authors propose conducting further research to establish and formalize this responsibility. Without such institutionalization and legalization, the efficacy of this method, along with numerous others, remains akin to "milking the ram."

REFERENCES

Abdelhameed, W. (2018). BIM in architecture curriculum: a case study. Architectural Science Review, 61(6), 480-491.

Abdelmohsen, S., Massoud, P., Tarabishy, S., & Hassab, A. (2017). Rule-based vs. intuition-based generative design: an inquiry into the digital chain concept in undergraduate architectural education. *International Journal of Parallel*, Emergent and Distributed Systems, 32 (sup1), S199-S209.

Allsop, Y. (2019). Assessing computational thinking process using a multiple evaluation approach. *International journal of child-computer interaction*, 19, 30-55.

Andia, A. (2002). Reconstructing the effects of computers on practice and education during the past three decades. *Journal of Architectural Education*, 56(2), 7-13.

Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society*, 19(3), 47-57.

Barnett, R., Parry, G., & Coate, K. (2001). Conceptualising curriculum change. Teaching in Higher Education, 6(4), 435-449.

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. Learning & Leading with Technology, 38(6), 20-23.

Bergström, A. (2014). Architecture and the rise of practice in education. Architectural Theory Review, 19(1), 10-21.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). Developing computational thinking in compulsory education implications for policy and practice (No. JRC104188). Joint Research Centre (Seville site).

Colquhoun, A. (1989). Modernity and the classical tradition: architectural essays, 1980-1987. MIT Press.

Craveiroa, F., Duartec, J. P., Bartoloa, H., & Bartolod, P. J. (2019). Additive manufacturing as an enabling technology for digital construction: A perspective on Construction 4.0. sustainable development, 4, 6.

Fonseca, D., Redondo, E., Valls, F., & Villagrasa, S. (2017). Technological adaptation of the student to the educational density of the course. A case study: 3D architectural visualization. Computers in Human Behavior, 72, 599-611.

Forty, A., & Forty, A. (2000). Words and buildings: A vocabulary of modern architecture (Vol. 268). London: Thames & Hudson.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. Educational researcher, 42(1), 38-43.

Guney, D. (2015). The importance of computer-aided courses in architectural education. Procedia-Social and Behavioral Sciences, 176, 757-765.

Hambrusch, S., Hoffmann, C., Korb, J. T., Haugan, M., & Hosking, A. L. (2009). A multidisciplinary approach towards computational thinking for science majors. ACM SIGCSE Bulletin, 41(1), 183-187.

Henri H., A. (2003). New Design Methods for Computer-Aided Architectural Design Methodology Teaching. *International Journal of Architectural Computing*, 1(1), 72–91.

Kazimoglu, C., Kiernan, M., Bacon, L., & MacKinnon, L. (2012). Learning programming at the computational thinking level via digital game-play. Procedia Computer Science, 9, 522-531.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). A validity and reliability study of the computational thinking scales (CTS). Computers in human behavior, 72, 558-569.

Liu, H., & Wang, P. H. (2020). Digital Architecture Teaching System at ETH Zurich. Design Engineering, 914-930.

Lynn, G. (2002). Intricacy Exhibition Catalogue. ICA, University of Pennsylvania.

Mueller, J., Beckett, D., Hennessey, E., & Shodiev, H. (2017). Assessing computational thinking across the curriculum. In Emerging research, practice, and policy on computational thinking (pp. 251-267). Springer, Cham.

Phocas, M. C., Michael, A., & Fokaides, P. (2011). Integrated interdisciplinary design: the environment as part of architectural education. *Journal of Renewable Energy & Power Quality*, 9, 501.

Reiser, J., & Umemoto, N. (2006). Atlas of novel tectonics. Princeton Architectural Press.

Richey, R. C., & Klein, J. D. (2005). Developmental research methods: Creating knowledge from instructional design and development practice. *Journal of Computing in Higher Education*, 16(2), 23.

Rodriguez, C., Hudson, R., & Niblock, C. (2018). Collaborative learning in architectural education: Benefits of combining conventional studio, virtual design studio and live projects. *British Journal of Educational Technology*, 49(3), 337-353.

Rowland, S. (2006). The Enquiring University: n/a. McGraw-Hill Education (UK).

Schenk, P. (2005). Reflections on the teaching of drawing in the digital age: attitudes of senior academics in the United Kingdom to the place of drawing tuition on the design curriculum in higher education. Art, Design & Communication in Higher Education, 4(3), 189-203.

Schmitt, G. (2015). Civic Engagement and Big Data Informed Urban Design in Future Cities. 건축, 60(1), 22-25.

Selby, C., & Woollard, J. (2013). Computational thinking: the developing definition.

Soliman, S., Taha, D., & El Sayad, Z. (2019). Architectural education in the digital age: Computer applications: Between academia and practice. *Alexandria Engineering Journal*, 58(2), 809-818.

Valls, F., Redondo, E., Fonseca, D., Torres-Kompen, R., Villagrasa, S., & Martí, N. (2018). Urban data and urban design: A data mining approach to architecture education. Telematics and Informatics, 35(4), 1039-1052.

Vergara, C. E. (2015). Towards a Framework for Assessing Computational Competencies for Engineering Undergraduate Students. age, 26, 1.

Wangler, T., Roussel, N., Bos, F. P., Salet, T. A., & Flatt, R. J. (2019). Digital concrete: a review. Cement and Concrete Research, 123, 105780.

Willmann, J., Gramazio, F., & Kohler, M. (2015). Gramazio Kohler Research, Automated Diversity: New Morphologies of Vertical Urbanism. Architectural design, 85(6), 122-127.

Wing, J. (2006). Computational Thinking, communication of the ACM, n 49.

AUTHOR (S) BIOSKETCHES

M. Kheirollahi., *Department of Architecture, Mashhad Branch, Islamic Azad University Mashhad, Iran*
Email: *dr.mehrankheirollahi@gmail.com*

S. Safarnezhad., *Department of Architecture, Mashhad Branch, Islamic Azad University Mashhad, Iran*
Email: *sr.safarnezhad@yahoo.com*

HOW TO CITE THIS ARTICLE

Kheirollahi, M,. Safarnezhad, S. (2023). Educational Structure in Digital Architecture; Challenges and Opportunities. *Int. J. Architect. Eng. Urban Plan*, 33(4): 1-16, https://dx.doi.org/ijaup.648.

URL: http://ijaup.iust.ac.ir