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Examining Technology Adoption Trends in Studio-Based Learning

Noor Hafizah[1&2], Mohd Zairul[2&3]

[1]Faculty of Information Sciences and Engineering, Management and Science University, Shah Alam Selangor, Malaysia, [2]Department of Architecture, Faculty of Design and Architecture, UPM Serdang, Selangor Malaysia, [3]Institute for Social Science Studies, Universiti Putra Malaysia, Serdang Selangor, Malaysia

Email: gs65440@student.upm.edu.my

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Abstract

In the context of studio-based learning, technology adoption has developed into a significant emergent technology in the fields of architecture, interior architecture, and landscape architecture. With the rapid advancement of technology, Industrial Revolution 4.0 is continuously evolving in unexpected ways in higher education. Studio-based learning, especially in architecture education, offers students access to various technology tools, enhancing their creativity and boosting interactive communication. However, the literature lacks studies about technology adoption in studio-based learning. Therefore, the aim of this study is to gather and review patterns and trends in the use of technology adoption in studio-based learning, from pre to post covid pandemic. This thematic review paper (TR) aims to synthesize literature from 2018-2023 on the technology adoption in studio-based learning using Atlas. ti 23. Thematic review (TR) from Scopus, Science Direct, IEEE, and Web of Science (WoS) had been employed, covering 134 peer-reviewed journal articles, which then had been analyzed in terms of Collaborative technologies with BIM, Digital Fabrication with CAD, and Integrated Metaverse. This thematic review offers an overview of the need for the personalization of digital technology in post-pandemic and future studio education. The findings and recommendations shall help future researchers in further exploring the use of technology in studio education, to cater to students' personalization and needs of post-pandemics.

Keywords: Technology in Education, Higher Education, Post Covid-19, Future Education, Studio-Based Learning, Studio Education

Introduction

Studio learning is a pedagogical approach that is widely used in design education. It is considered a signature pedagogy in design education, providing a dominant learning environment and mode of delivery (Crowther, 2013). The studio environment offers unique advantages for learning, such as fostering collaboration, creativity, and critical thinking

(Sochacka et al., 2016). In professional fields such as the arts, design, architecture, and planning, where visualization plays a significant role, the adoption of technologies has become essential. Technology in education has advanced significantly in recent years, leading to the development of interactive methods of education delivery, termed technology-enhanced learning (TEL). This improves the diversity of education delivery (Hendricks, 2022). Industry 4.0 and the COVID-19 pandemic, by chance, are shaping the future of higher education, industry, and organizations, acting as catalysts for digitalization of education, but not without challenges revolving around mobile connectivity, collaboration, and blended teaching and learning. Many design schools around the world have adapted digital design concepts in their curricula. In fostering design education and pedagogy, researchers have imparted theoretical, computational, and cognitive approaches to digital design (Gul & Simisic, 2017). However, the integration of technology in studio learning has both benefits and challenges.

The intent of this study is to explore technology adoption in studio-based learning at higher education before and after pandemic impacted higher education. Typically, educators practice traditional methods of transferring knowledge to learners, which are typically delivering information to learners who are expected to listen, comprehend, and later manipulate the content or material being presented. The study (Hoss et al., 2022) found the need for sufficient digital literacy skills for students and educators to navigate the technology used in higher education more effectively. The lack of digital literacy may lead to frustration and delay students' learning. The originality of this study is in discovering what has been discussed on the technology adoption in studio-based learning at higher education before and after the pandemic impacted higher education.

The current education should promote inclusivity and equality, in line with the objectives of Sustainable Development Goal 4 (SDG4) to promote lifelong learning in higher education. Teaching in the age of IR4.0 highlights multiple teaching challenges and the need to push boundaries to the higher-level education, to opt for incorporation of technology into their instructional strategies. Therefore, the purpose of this study is to explore some current trends of technology adoption in studio-based learning at higher education level, followed by examining potential technology that can cater to student personalization for future direction. The study also addresses the following research questions.

Research Question (RQ): What are the technology patterns and trends implemented in studio-based learning in the years 2018-2023?

Materials and Methods

Zairul (2020, 2021); Zairul et al (2023); Zairul & Zaremohzzabieh (2023) introduced ATLAS.ti 23 as a platform to conduct thematic reviews, which has been implemented in this study to conduct approach of thematic analysis on literature review. Clarke et al (2012) defined thematic analysis as a systematic process that entails a meticulous and comprehensive reading of the subject matter to identify patterns and construct themes. In essence, the goal of thematic analysis is to better comprehend the information, by uncovering meaningful and relevant themes that may not have been initially apparent. A thematic review (TR) involves identifying, analyzing, and synthesizing themes or patterns in the existing research on a specific subject in the literature review (Zairul, 2023). According to Zairul & Zairul (2020), ATLAS.ti software is useful and helpful in this process, as it facilitates more efficient and precise data analysis, in addition to identifying patterns and themes within the research.

ATLAS.ti can assist in writing TR by providing the tools to handle and cite literature, formulating research themes and inquiries, depicting theoretical frameworks, and integrating research materials. The software's functionalities can help in enhance the process of thematic analysis and ensure that the review adheres to a standard of consistency and rigor. Furthermore, the incorporation of qualitative data analysis software like ATLAS.ti has become a prevalent practice in the review paper process, particularly in the analysis of textual content from research articles and interview transcript. The utilization of software also can enhance the precision and efficiency of the analysis process and maintain a standard of consistency and rigor.

The next stage is to identify that pattern and create a theme to comprehend the trend of technology adoption publications. The selection of literature was performed according to several selection criteria: 1) publication from 2018-2023, 2) to have at least keyword(s) technology adoption, studio-based learning, higher education 3) Focusing is on technology trends at higher education. The decision not limited to any country of origin was made to help define technology adoption trends in a studio-based learning context.

Table.1
Scopus, Science Direct, WoS, and IEEE keywords

Databases	***Search Strings***	***Results***
SCOPUS	(TITLE-ABS-KEY (technology) AND TITLE-ABS-KEY ("architecture education") OR TITLE-ABS-KEY ("interior design education")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j"))	18 results
SCIENCE DIRECT	technology AND "architecture education" OR "interior design education"	65 results
WOS	technology (All Fields) AND "architecture education" (All Fields) OR "interior design education" (All Fields) and Review Article (Exclude – Document Types)	23 results
IEEE	("All Metadata":"technology) AND ("All Metadata":"architecture education") OR ("All Metadata":"interior design education")	31 results

Source: Author, 2023

The literature search was performed using Scopus, Science Direct, WoS and, IEEE. The initial search came out with 18 results from Scopus, 65 from Science Direct, 23 from WoS, and 31 from IEEE. Of all, 101 articles were removed due to duplication and the studies are not eligible and related to research questions. Some articles were also found as "review papers not accessible". Therefore, the number of final papers to be reviewed was down to 29 articles (Table 1). All these documents were then grouped into 1) author, 2) Issue number, 3) periodical, 4) publisher, 5) volume, and 6) year of publication. By doing so, the articles could be analyzed according to the year it was published and the trend discussion to the year. The

total number of articles finalized in ATLAS.ti was 29 documents. The 29 remaining metadata were transferred and established as primary documents in ATLAS.ti 23. Based on metadata created in Mendeley, several groupings were automatically generated in the group code. This review findings would then be split into two categories, which are quantitative and qualitative findings.

Table. 2
Thematic Review Methodology (Zairul, 2023)

Databases	***Search Strings***
Research Question (RQ) Formulation (Formulate)	The formulating structuring of RQ involves defining a query that serves as a guide for the following steps.
Article Screening	Identifying relevant studies and making decisions based on the search location, search terms, sources, and time frame.
Article Filtering	Inclusion and exclusion criteria are utilized in this phase. These criteria are determined based on the RQ, study objectives, and insights gained from reading relevant papers. To ensure accurate selection of articles, they will be filtered and added to Mendeley for further refinement, which is a final round of filtering
Finalize Articles	To make sure that only pertinent articles are chosen for the analytic process, article information will be double-checked in Mendeley.
Synthesize	This phase involves the process of thematic analysis to develop themes based on extensive reading on the subject matter using the Atlas.ti 23

Source: (Zairul et al., 2023)

The Clarivate Analytics' Scopus, Web of Science, Science Direct, and IEEE databases were used to provide an in-depth topic overview due to the disparate key subject areas. Due to the size of its collection of peer-reviewed publications, Scopus was selected, while Web of Science was selected since it contains all indexed journals with measurable impact factors in the journal citation report (JCR). IEEE and Science Direct were chosen as their journals focused on technology and architecture education. General keywords that reflect technology adoption, studio education, architecture education, and interior design education were keyed in the search strings. For data processing, these articles were uploaded to Mendeley Desktop. Consequently, the authors' name, year, and abstract were updated, to ensure correct metadata.

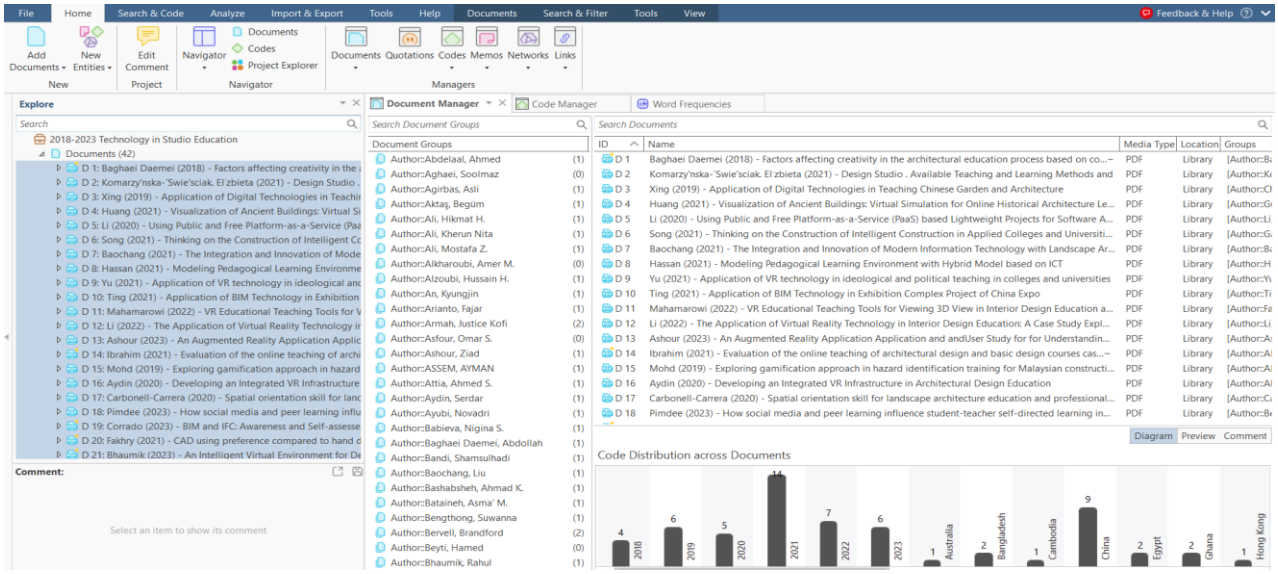

Figure.1 The Mendeley metadata is used for the formation of the group.
Source: Author, 2023

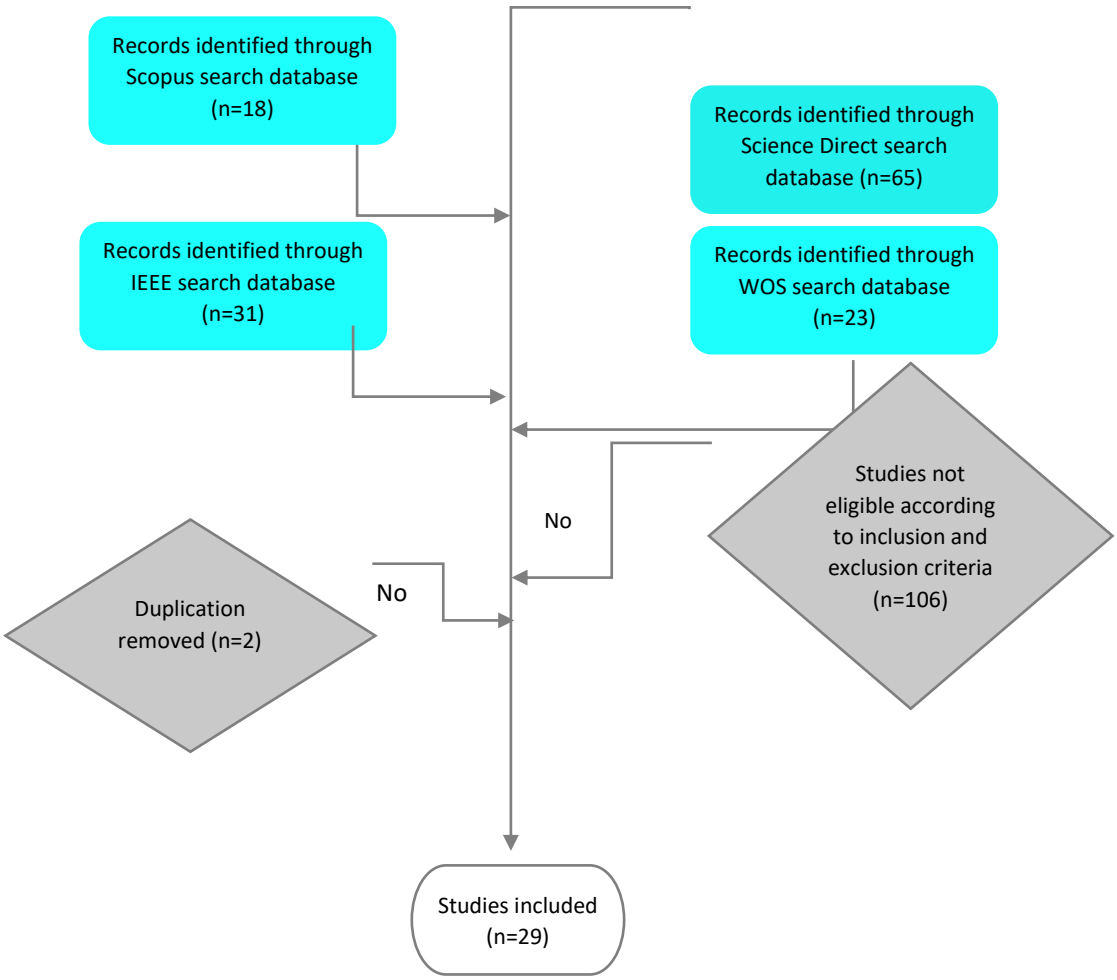

Figure 2 Inclusion and exclusion criteria in the thematic review
Source: Author, 2023

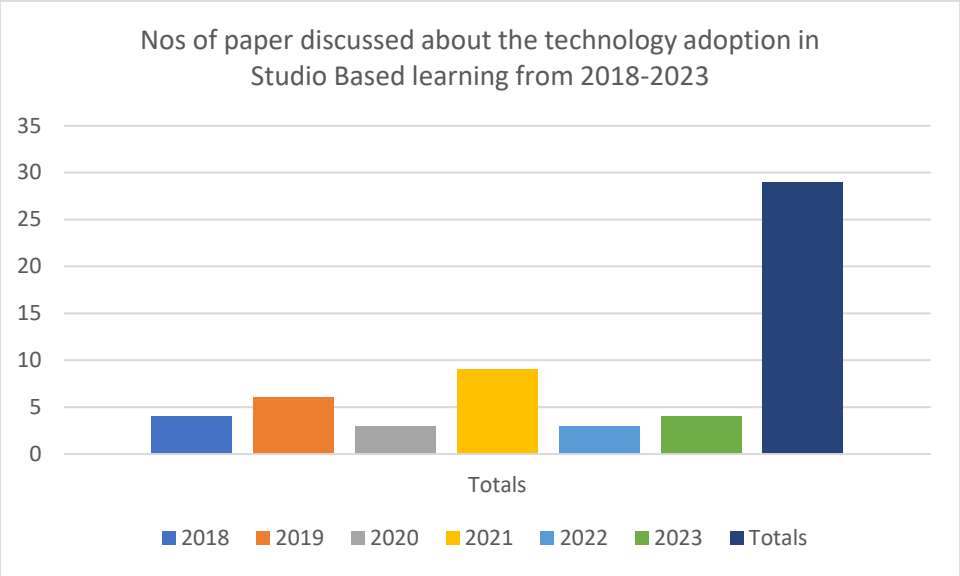

Figure. 3 Breakdown of articles by year of publication
Source: Author, 2023

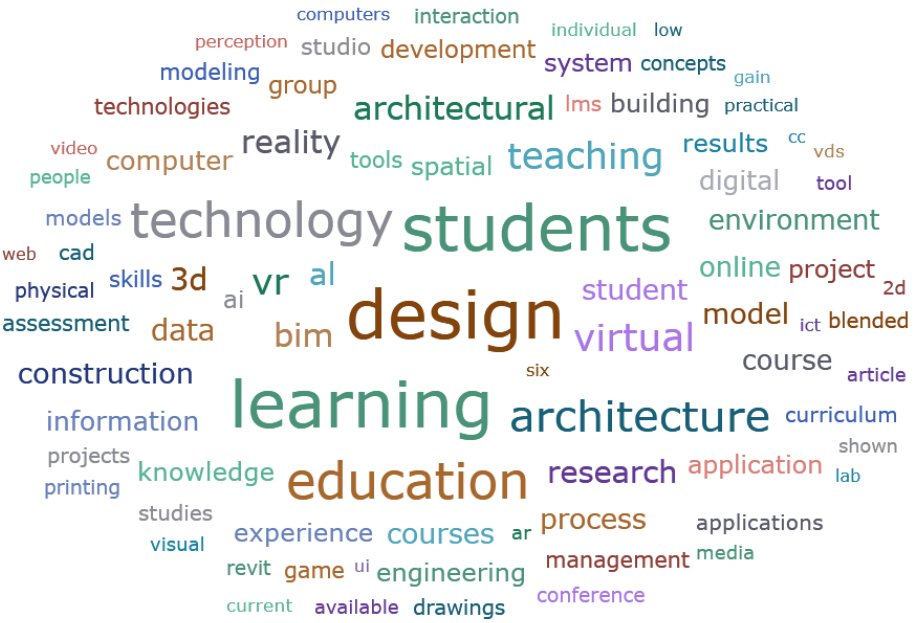

Figure. 4 Word cloud of the word and term frequencies generated from 29 articles.
Source: Author, 2023

Figure 3 shows the number of publications versus year. The data demonstrates that the year which discusses most technology adoption in studio-based learning is 2021. The figure indicates that there are increasing numbers from 2020 to 2021 in implementation of technology in studio learning. The results show that the Covid-19 pandemic has led to a rise in the number of studio-based learning contexts using technology. The growing number is a result of the requirement to adjust and continue schooling despite physical constraints. By technology, teachers and students were able to simulate some parts of studio-based learning in virtual environments, guaranteeing educational continuity and fostering engagement, collaboration, and creativity despite the difficult conditions. Figure 4 presents the word cloud, which shows the most mentioned words from 29 articles are virtual, application, and virtual

reality. Other terms include interactive, environment, computers, 3D, artificial intelligence, and BIM.

Result and Discussion

The TR's findings were then categorized into two: quantitative findings and qualitative findings. The report produced descriptive data in the quantitative section based on the geographical distribution of publications and the research tendencies in each country.

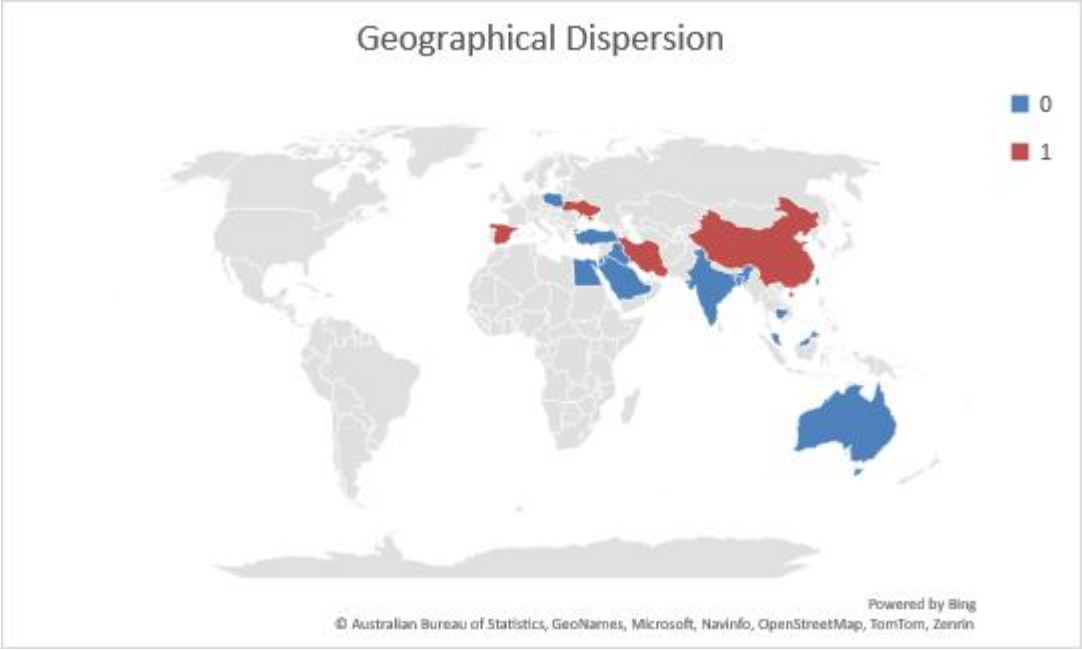

Figure. 5 Geographical Dispersion
Source: Author, 2023

Quantitative Results

This section reports the key findings of the thematic review. The geographical dispersal of the study was identified based on the Sankey chart in Figure 6 which was automatically generated from Atlas. ti 23. Saghafi & Crowther (2021**)** examined the integrated function of technology in Australian architectural education and then provided criticism of the technology instruction in design studios. Including technology-related topics in studio lessons. This study aimed to assist students in developing architectural knowledge and skill. A study by Fakhry et al (2021) discussed Computer-Aided Design learning preferences, compared to manual hand drafting in architectural technology and working drawing works. Their country mates, Ashour et al (2023) demonstrate the implementation of Metaverse technology in utilizing augmented reality to understand and learn architectural representations. The authors integrated the technology tools of Building Information Modelling (BIM) and Augmented reality tools with novel visualization features to support learning and understanding of construction systems materials, and then completed 3-Dimensional views of complex building structures. This study demonstrated that BIM and AR are relatively easy to use in architecture education. Huang et al (2021) proposed an online virtual simulation system for Historical Architectural learning, while Ting (2021) proposed the application of BIM technology in a complex project of China Expo in studio project. Mahamarowi et al (2022) explored the development of VR educational tools using the ADDIE model and put students to Interior Design test in the design process. Meanwhile, Li & Xie (2022) explored learners' acceptance in the implementation of VR in

studio education. Ibrahim et al (2021) conducted comparison between online learning and offline learning of architecture students in basic design course.

The results of this paper are both quantitative and qualitative. 29 research articles had been reviewed iteratively, with comparisons of similarities and differences. Several journals from Engineering Journal, Journal of Planning Education, and Research Land and Architectural Research are the three most popular journal choices for architectural researchers. Table 3 lists the publications that were discovered based on conferences and journals by year. The table shows that most publications on the use of technology in studio-based learning are from the year 2021. There are also publications discovered in relation to periodicals and conferences over time. Generally, 2021 has the greatest number of publications on the use of technology in studio-based learning.

Table. 3
Publications according to periodicals and conference vs year.

	2018	***2019***	***2020***	***2021***	***2022***	***2023***	***Totals***
International Conference on Educational T	-	-	-	1	-	-	**1**
International Conference on Consumer Electronics and Computer Engineering,	-	-	-	-	1	-	**1**
Engineering and Technology for Sustainable Architectural and Interior Design Environments,	-	-	-	-	1	-	**1**
IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops	-	-	-	-	-	1	**1**
Ain Shams Engineering Journal	-	-	-	1	-	2	**3**
Alexandria Engineering Journal	-	2	-	-	-	-	**2**
Archnet-IJAR	-	-	-	1	-	-	**1**
Croatian Journal of Education	1	-	-	-	-	-	**1**
Frontiers in Robotics and AI	-	-	1	-	-	-	**1**
Frontiers of Architectural Research	1	-	1	-	-	-	**2**
International Journal of Built Environment and Sustainability	-	1	-	-	-	-	**1**
Innovative Technology and Exploring Engineering	-	1	-	-	-	-	**1**
Journal of Computational Design and Engineering	-	1	-	-	-	-	**1**
Journal of Higher Education Theory and Practice	-	-	-	1	-	-	**1**
Land	-	-	1	2	-	-	**3**
Procedia Computer Science	-	-	-	-	-	1	**1**
International Conference on Big Data and Informatization Education	-	-	-	1	-	-	**1**
International Conference on Internet, Education and Information Technology	-	-	-	1	-	-	**1**
Social Sciences & Humanities Open	-	-	-	-	2	-	**2**
IEEE International Conference on Engineering, Technology and Education	-	2	-	-	-	-	**2**
Telematics and Informatics	1	-	-	-	-	-	**1**
Totals	4	6	3	8	3	4	**29**

The 29 research articles had been reviewed iteratively, with comparisons of similarities and differences.

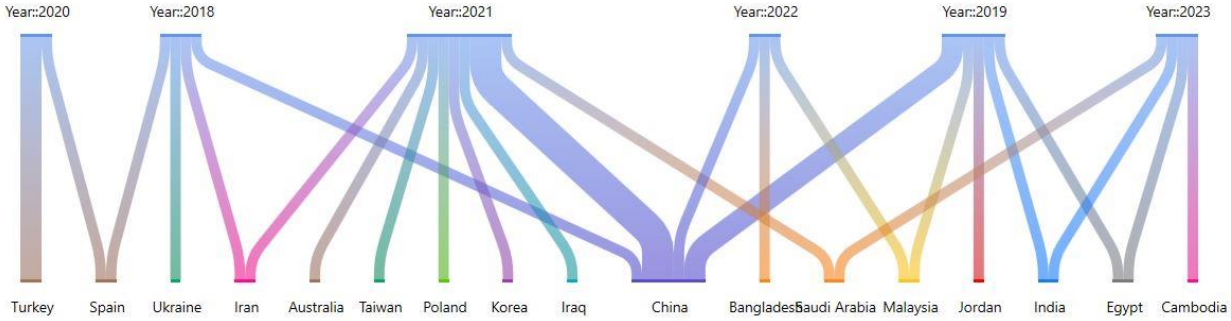

Figure. 6 Issues discussed in literature.
Source: Author, 2023

Table.4
The distribution of articles by country – and year.

	2018	***2019***	***2020***	***2021***	***2022***	***2023***	***Total***
Australia	-	-	-	1	-	-	**1**
Bangladesh	-	-	-	-	1	-	**1**
Cambodia	-	-	-	-	-	1	**1**
China	1	2	-	3	1	-	**7**
Egypt	-	-	-	-	-	1	**1**
India	-	1	-	-	-	1	**2**
Iran	1	-	-	1	-	-	**2**
Iraq	-	-	-	1	-	-	**1**
Jordan	-	1	-	-	-	-	**1**
Korea	-	-	-	1	-	-	**1**
Malaysia	-	1	-	-	1	-	**2**
Poland	-	-	-	1	-	-	**1**
Saudi Arabia	-	-	-	1	-	1	**2**
Spain	1	-	1	-	-	-	**2**
Taiwan	-	-	-	1	-	-	**1**
Turkey	-	-	2	-	-	-	**2**
Ukraine	1	-	-	-	-	-	**1**
Totals	4	6	2	10	3	4	**29**

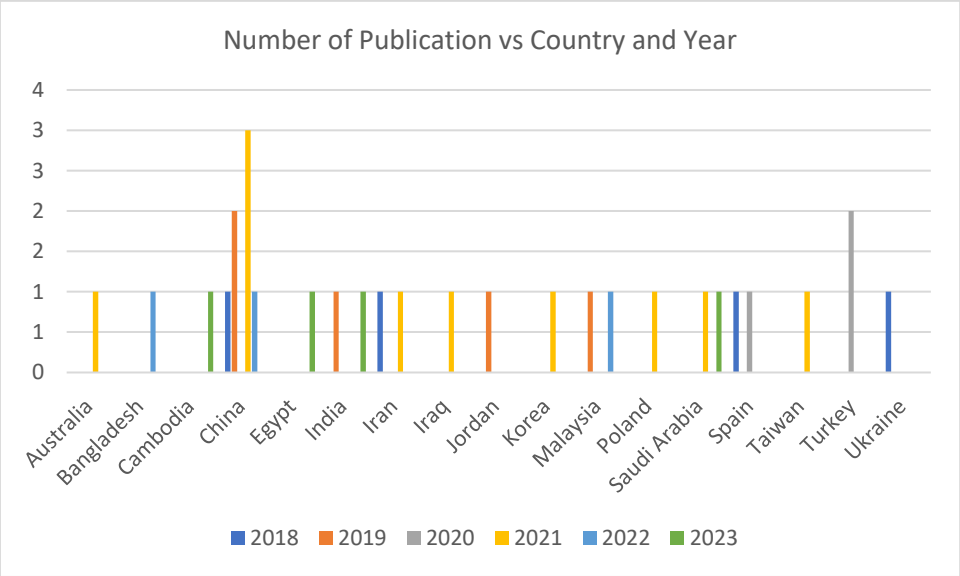

Figure. 7 Number of publications vs country and year
Source: Author, 2023

The number of publications is plotted by country and year in Table 4. The table demonstrates that China is the leading country, with the most journal and publications. 2021 is the year with the most published articles, while there is increasing number of publications from 2020 to 2021, and which then shows a decrease in 2022.

Research Question (RQ): What are the technology patterns and trends implemented in studio-based learning in the years 2018-2023?

Qualitative Results

The qualitative component of this paper thoroughly examines any new themes pertaining to research issues. As demonstrated in Table 5, the pattern was examined based on the study year as opposed to themes. The finding indicated that trends in the technology adoption in studio learning began in 2018, to year 2023. From the directions and topics of the articles, three themes could be deduced, as listed in Table 5.

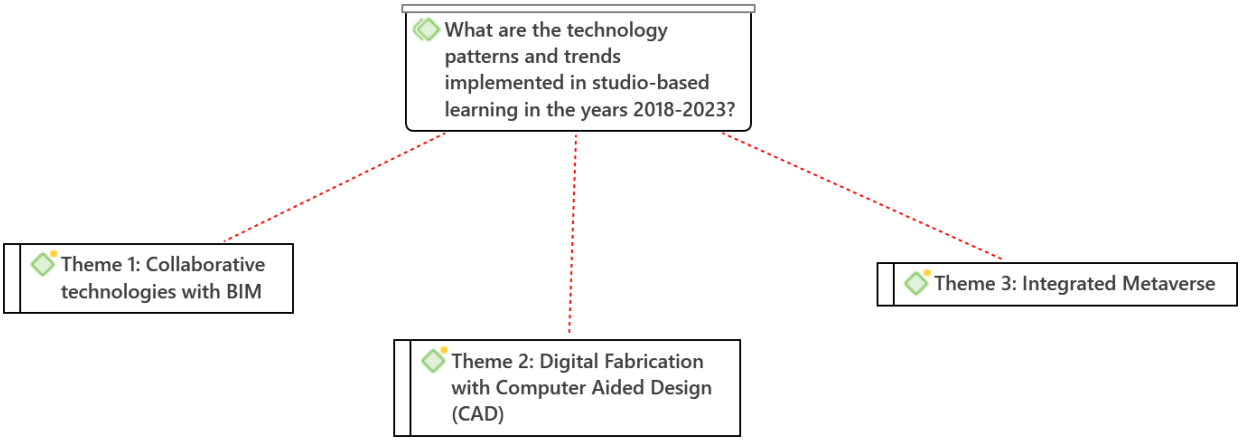

Figure. 8 Overall Network to answer Research Question (RQ).
Source: Author, 2023

Table.5
Themes according to the year

Year/Theme	2018	2019	2020	2021	2022	2023	Total
Collaborative technologies with BIM	-	-	1	2	1	1	**5**
Digital Fabrication with Computer Aided Design (CAD)	3	1	-	3	-	-	**7**
Integrated Metaverse	1	5	2	4	2	3	**17**
Totals	**4**	**6**	**3**	**9**	**3**	**4**	**29**

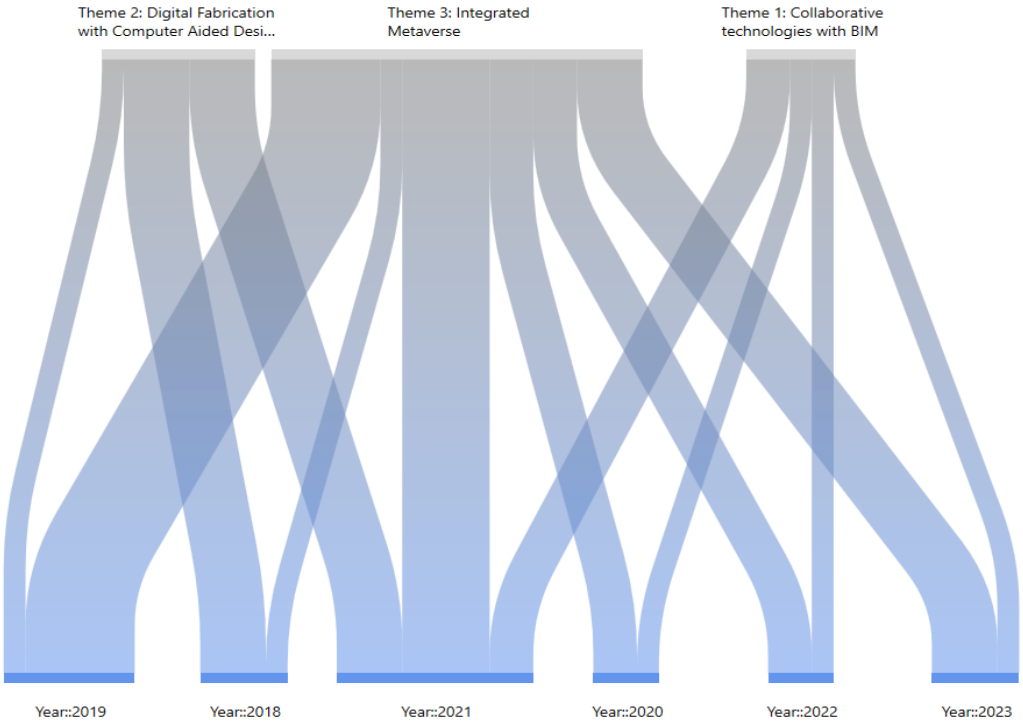

Figure. 9 Year of publications versus themes.
Source: Author, 2023

Theme 1: Collaborative Technologies with Building Information Modelling (BIM)

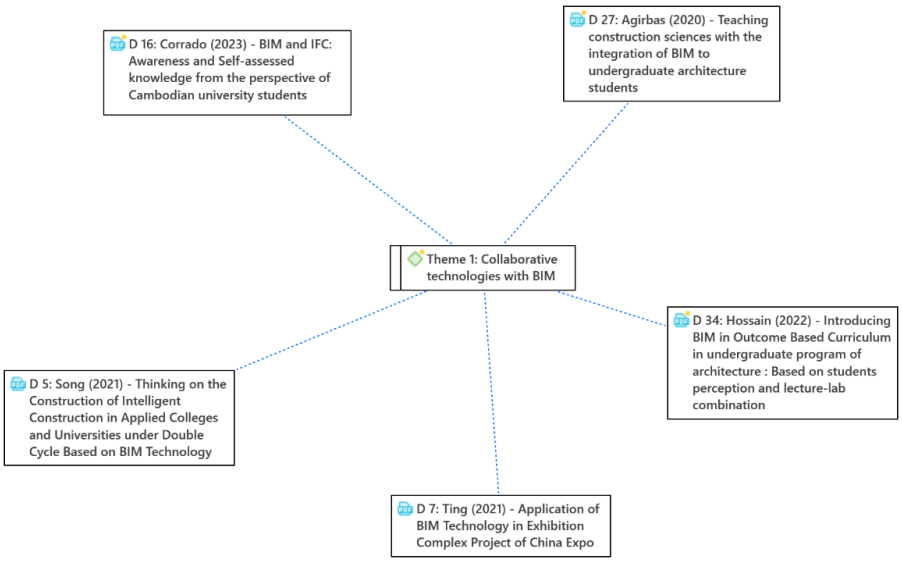

Figure. 10 Collaborative technology's themes with BIM overall networks.

Building information modelling, or building information management, (BIM) processes are made more effective and efficient with the help of collaborative technology. A building or infrastructure project's geometry, spatial linkages, geographic information, quantities, and component attributes are included in a BIM, which is a digital representation of the project. Throughout the course of the project, it enables stakeholders to work together and reach wise choices. The use of BIM technology in collaborative work, particularly during the construction stage, focuses primarily on overall construction planning, which includes preparation for construction, layout for construction, design for construction organisation, scheme for construction, progress plan for construction, and technical disclosure. By offering tools and platforms that make it easier for project participants to communicate, coordinate, and share data, collaborative technologies are frequently employed to enhance BIM. According to Hossain & Bin Zaman (2022), studio-based learning and building studies can both gradually transition from two-dimensional (2D) and three-dimensional (3D) Computer Aided Design (CAD) to BIM. BIM is technology, not software. Through the construction of sophisticated, multi-dimensional building models, BIM fundamentally involves a transition from two- to three-dimensional architectural design (Hossain & Bin Zaman, 2022).
According to Ting (2021), Building information modelling (BIM) technology is used to create a comprehensive management platform for learning on building construction, project management, and safety management. As stated Song, Gan, & Meng (2021), BIM technology is a product of the new revolution in architecture and construction education. This claim is supported by the fact that the building industry has demonstrated a growing interest in adopting building information modelling (BIM); acknowledging the many advantages and resource savings during the design, planning, and construction of new structures (Corrado et al., 2023). Additionally, Agirbas (2020) proposed a study with two hypotheses: (1) If the student has a positive attitude toward the use of the BIM program, then efficiency by which construction science is taught by its means is improved; and (2) If the student has a positive attitude toward the use of the BIM program, then efficiency by which construction science is taught by its means is improved (Hypothesis 2).

Corrado et al (2023) first explored the adoption and application of BIM and Industry Foundation Classes (IFC) principles in the tertiary architecture education curriculum, as viewed from the viewpoint of university students in Cambodia. The study was conducted by quantitative approach using questionnaire generated using Google Form. According to the study, the findings showed that BIM education has not been widely adopted in Cambodia's higher education system, with students indicating little knowledge of BIM in their own assessments. Another study by Hossain & Bin Zaman (2022) introduced Building Information Modelling technology in the undergraduate program according to Outcome Based Curriculum (OBC). The study demonstrates that it is inevitable to execute ArchiCAD and BIM software for undergraduate students' study. The authors presumed that by the time students have a fundamental understanding of architectural drawings and modelling in the second or third semester, it would be an ideal time to introduce BIM technology. However, despite three weeks of lectures and weeks of lab, the course's final evolution revealed a lack of comprehension of BIM and modelling practice.

Therefore, this review reveals that collaborative technology enhances the effectiveness and efficiency of Building Information Modelling (BIM). In studio-based learning and building studies, the switch from two-dimensional (2D) and three-dimensional (3D) computer-aided design (CAD) to BIM is happening steadily. This implementation of studio learning and construction studies is considered a revolution in the design and construction phases. Nonetheless, there are still challenges in terms of implementation, curriculum integration, and students' proficiency. Therefore, there is a need for more comprehensive and effective educational strategies to enhance students' proficiency and curriculum strategies for adopting BIM technology.

Theme 2: Digital Fabrication with Computer Aided Design (CAD)

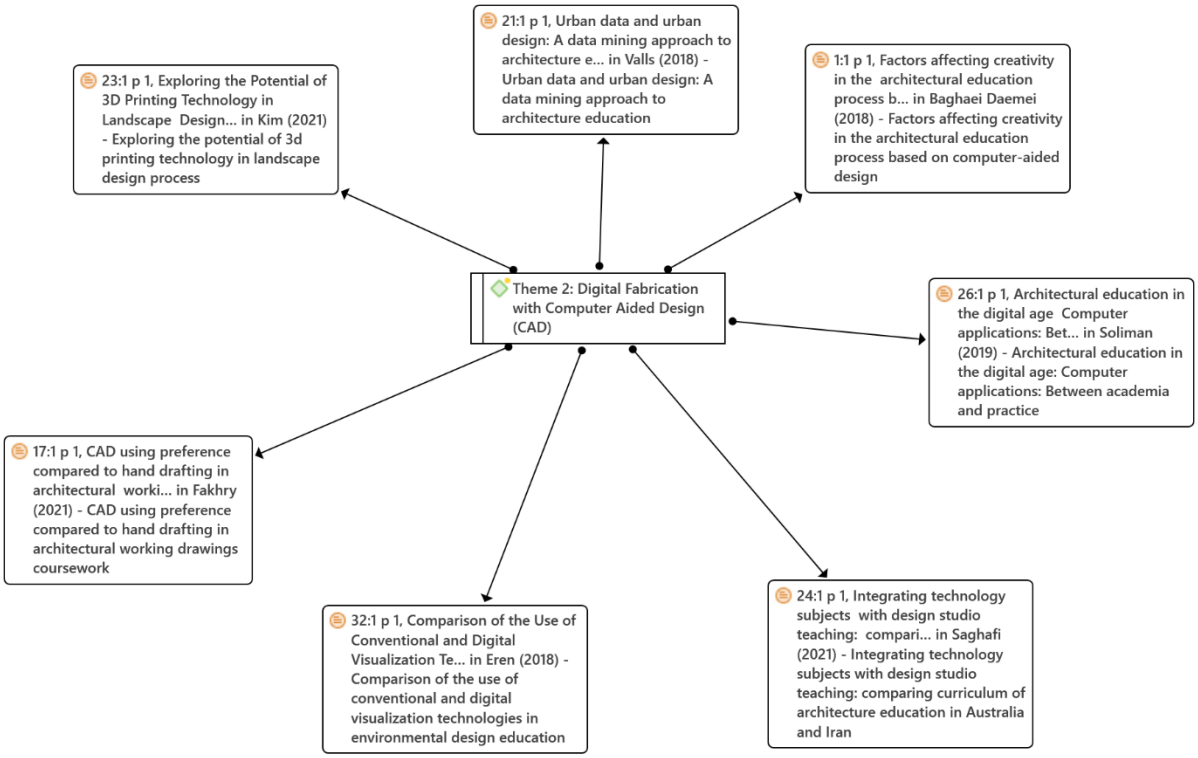

Figure. 10 Digital Fabrication with Computer Aided Design (CAD) overall networks. Source: Author, 2023

Computer-aided design is a method for creating virtual three-dimensional models and two-dimensional drawings utilizing computers and specialized software (CAD) (Fakhry et al., 2021). Numerous academies have contributed to the innovative design and variety of design processes, and the discipline of architectural design has seen many advancements in the application of Computer Aided Design (CAD) in studio education (Daemei & Safari, 2018). According to Soliman et al (2019), Computer-aided design is a process that involves using computers and specialized software to create virtual three-dimensional models and two-dimensional drawings.

3D design and printing are gaining preferences, but still face unavoidable issues. Many years back, Computer Aided Design software was vastly used by studio education in producing technical drawing, 2D drawing or drawing documentation. Kim et al (2021) examined the implication of 3D printing technology as Computer Aided Design in landscape studio education; in the end, they concluded that 3D printing has limitations in terms of cost, delivery time, scale, and level of detail. The working drawing course is an essential component of studio education, but many students in architecture or interior architecture education struggle to understand working drawing when using only CAD in preparation or production, which highlights the significance of addressing the CAD preference in working drawings works. Fakhry et al (2021) evaluated educators' and students' preferences for the computer-aided design (CAD) or traditional hand drafting in working drawings. The study showed that students and educators preferred using CAD software, compared to the hand drafting method in achieving the working drawing in terms of accuracy, neatness, ease of modification, overall quality, and cost efficiency. According to the survey finding, most educators and students admitted preferring CAD in completing working drawing for their studio project. Eren et al (2018) emphasized the approaches used most frequently in the various studio learning stages, as well as the benefits of utilizing computer-aided design and digital presentation methods with visualization software. To ascertain the degree of student satisfaction, a study was carried out with the Landscape Architecture Department at Karadeniz Technical University (KTU). Due to the superior software attributes, the finding indicated that students were more satisfied using computer-aided design and digital technologies compared to conventional approaches.

Saghafi & Crowther (2021) demonstrated two possibilities for the integration of computer aided design with the design studio in architecture education. The study finding confirmed the need for all studio education course to be aware in dealing with digital technology and computer-aided design to be growingly globalized context. The papers highlighting technology adoption in studio learning included in this thematic review paper mainly focus on computer-aided design. Soliman et al (2019) In order to examine the current state of education both nationally and internationally, it was suggested that computer applications be integrated into the top 20 international architecture schools as well as eight architectural departments in Egyptian universities. The researchers conducted a survey among architects to investigate professional needs in various architectural fields. In order to analyze how computers are currently used in the architectural profession, five main topics of analysis were created: 1) The function of computers in the design of interior and exterior architecture, urban planning, landscape architecture, and studio education; 2) The stages of computer-aided design in the architectural phase The usage of software in the workplace, the newest emerging trends, and the latest developments in the architectural fields round out the list. 5) Any distinctions in the mindsets of various architecture students. It should be beneficial to develop a global structure for computer-aided education to be a guide for studio learning in developing countries. A survey was conducted in Iran, among 347 master students and 114 bachelor students of architecture who enrolled in studio-based learning. According to the study, sketching, physical modelling, experience, and visual references are indeed effective tools to foster creativity during the design process. The findings indicated favorable opinions on the use of CAD tools for studio instruction. Only 7% of the participants, however, concurred with the premise that sketches encourage creativity.

As digital technologies and CAD continue to evolve, it is crucial for institutions to stay updated with the latest trends and advancements. Institutions and educators should augment the use of 3D printing technologies, as well as assess the feasibility and practicality of implementing 3D printing technology. This thematic review indicates new developments or advancements in CAD are expected to begin from the year 2021, focusing on metaverse, augmented reality, virtual reality and mixed reality. Furthermore, institutions should also assess the feasibility and practicality of implementing 3D printing technology within their curriculum. This involves considering factors such as cost, accessibility to equipment, and the potential impact on existing teaching methods. By carefully evaluating these aspects, institutions can make informed decisions about incorporating 3D printing into their CAD programs.

Theme 3: Integrated Metaverse

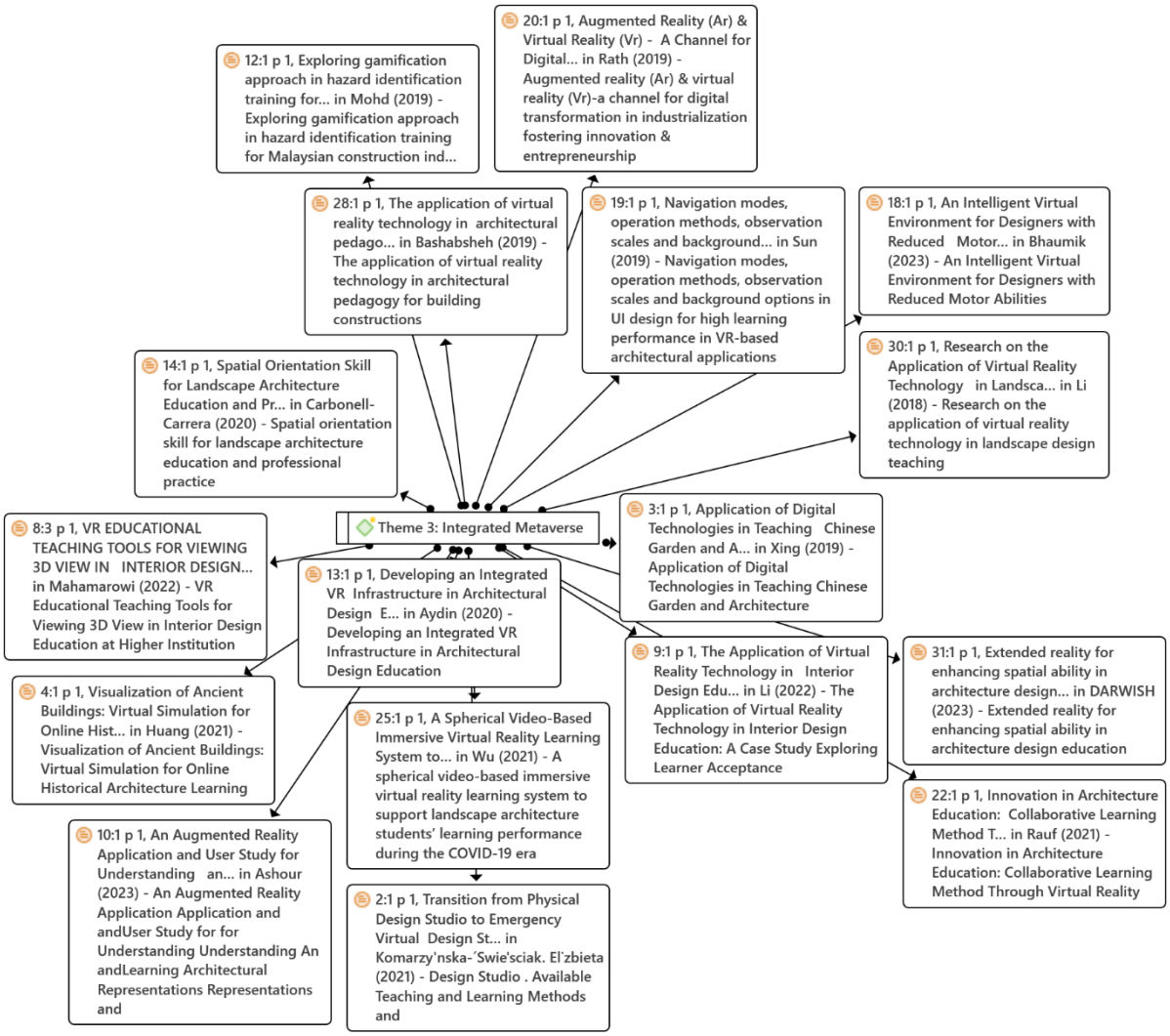

Figure. 11 Integrated Metaverse theme overall networks.
Source: Author, 2023

Industry 4.0, fourth generation industrialization, has taken its place in every nation. According to Rath et al (2019), a virtual world that incorporates multiple virtual reality (VR), augmented reality (AR), extended reality and other immersive technologies is referred to as an integrated metaverse. An integrated metaverse could provide innovative and immersive chances for students to engage in creative and collaborative activities in a virtual environment when used in the context of studio learning. Rath et al (2019) discussed about Industry 4.0 on construction course in higher learning education, inclusive of IT-enabled services and technological impact, along with the role of AR with its benefits and application in construction sector. The interaction of the body with the built environment should be taken into account in a holistic manner, where experience is embodied on a multidimensional level, in order to produce a spatial experience that is both functionally and aesthetically integrated. (Ceylanli & Yanas, 2021)

Gamification in learning is one of the perspectives in integrated metaverse that has been explored in education such as in architecture and city planning. Due to the nature of the building environment itself, it has been reported that the construction business has the third

highest record of workplace accidents, (Mohd et al., 2019). The authors sought to identify and investigate the variations across the gamification genres currently used in studio education, including simulation games, action games, and strategy games. The study reported that serious games are an appropriate genre to be adopted as an approach to learning and experience the construction industry in education. Students can take part in simulations, challenges, and quests online to improve their technical, analytical, and creative thinking skills in studio education. However, this thematic review article revealed a lack of research in gamification application guidelines and framework to enhance studio learning. Li et al (2018) explored the relationship between virtual reality (VR) in landscape architecture studio education. This study results showed that the introduction of computer virtual reality (VR) into the landscape design teaching in higher education had effectively improved teaching efficiency and sketch-up modelling helped in completing the virtual modelling of buildings and vegetation in landscape design.

Mahamarowi et al (2022) investigated the need to involve students in viewing 3D environment in spatial planning using virtual reality (VR). The authors used survey among first semester students to identify the most suitable method in exploring spatial design using VR in studio. This study aimed to improve the learning experience of interior design students in viewing 3D spatial for design development process. The study reported that the level of understanding in Interior Design context was more competent compared to the traditional method of learning. Similar research used case study to analyze the learner acceptance in implementing VR technology in ID education. The results showed immersion had influenced perceived usefulness because VR prototypes proved a sense of scene and realism. It also provided a unique sense of achievement for the interior design students. Bashabsheh et al (2019) developed computer software for building construction using VR technology. The software can produce 4D models for certain building construction phases in the design developments process using VR technology. The authors evaluated building construction course in architectural education at Jordan University of Science and Technology. The findings showed that the VR software achieved the three axes better than the conventional training methods. In studying architectural studio education, Aydin & Aktaş (2020) explored and examine the variations among the gamification genres already present in studio education, such as simulation games, action games, and strategy games. The results highlighted a tension between task-related and unrelated attributes. Despite receiving low marks for the practical attributes of perspicuity, efficiency, and dependability, using VR technologies in architecture design instruction is deemed to be appealing, interesting, and can boost creativity.

Darwish et al (2023), in Egypt based study the impact of the Extended Reality (XR) technology on students' overall spatial skill levels in the early design studio of architecture education. This study proved that XR technology can be used to improve spatial ability and looked at the association between the use of XR and a post-project general spatial skill test. However, this study also noted that two experiment group participants were unable to finish the test due to VR motion sickness. Nonetheless, XR technology is still new in studio education. Therefore, there is a need for higher institution to provide training and improve infrastructure in terms of studio environment that able to integrate with the XR technology. In another perspective by Sun et al (2019) a crucial component of studio education is to provide emphasis on how to use VR more effectively. The authors claimed that because studio instruction entails numerous learning processes involving 3D operations and objects, there is a significant opportunity to use VR technology to enhance learning outcomes. Thus, the study proposed

User Interface (UI) design of VR for studio learning that focused on operation modes, observation scales and background options. Another exploration in different types of technology by Ashour et al (2023) discover the integration of BIM with Augmented Reality (AR) as educational tools with novel visualization features to support learning and understanding construction systems, materials configuration, and 3D section views of complex building structures. The study validated through a test case based on a quasi-experimental research design, in which BIM x AR was used as an intervention. The author revealed the use of AR perceived significantly less workload and higher performance compared to the non-AR group.

The study concluded that the potential of VR in enhancing studio education in various disciplines, particularly in construction field, landscape, architecture, and interior design. Virtual reality (VR) or augmented reality (AR) immersion experiences can be provided through an integrated metaverse (AR). Three-dimensional models, prototypes, and artworks can be explored by students in a more participatory and dynamic way. They can virtually explore historical locations, art galleries, and museums to get ideas for their creative works. In another perspective, an integrated metaverse can offer immersive experiences for virtual reality (VR) or augmented reality (AR) (AR). Students can engage in more active and dynamic exploration of three-dimensional models, prototypes, and artworks. However, there is a need for further research and collaboration between academia and industries to explore the fusion of artificial intelligence (AI) and blockchain technologies with the metaverse for future studio education. The integrated metaverse has the potential to revolutionize studio-based education by providing immersive and interactive experiences for students. The concept of the metaverse, which combines the real and virtual worlds, has gained attention in the field of education due to its ability to enhance learning experiences and provide new opportunities for engagement.

Discussion and Future Studies

This thematic review paper highlights the most common pattern and trends in technology adoption in studio-based learning. The results of ATLAS.ti version 23' analysis revealed pattern and trends in technology adoption highlighted Collaborative technologies with BIM, Digital Fabrication with CAD and Integrated metaverse. Thematic review reports the increasing number of technology adoptions especially in pandemic era and the development of technology in education is more innovation especially in the technology of integrated metaverse. Future research opportunities in studio education are diverse. The need of more personalize learning instruction and flexibility education by adopting technology in studio learning will become future education 5.0 in studio learning. Technology integration in studio learning may be embraced for the future of studio education in accordance with the feedback that has been gathered from people all around the world regarding their preferences for learning and their acceptance of technology. On the other hands, numerous studies are raised regarding the improvement and implementation in building construction area of study.

Several discussions have been presented that could benefit students in learning building structure, drafting, simulation and the understanding of spatial organization and project planning. Collaborative technology enhances the effectiveness and efficiency of Building information Modelling (BIM). In studio-based learning and building, the transition from two-dimensional (2D) and three-dimensional (3D) computer-aided design (CAD) to BIM is occurring steadily. The emergence of Industrial Revolution 4.0 (IR4.0) has brought about rapid

advancements in technology. This thematic review paper emphasizes the importance of technology in education in enhancing students' performance, engagement, and flexibility in studio learning. Nonetheless, further research and advancements in VR applications, pedagogical approaches, and user experience design will contribute to the continued integration and successful implementation of advancements technology in studio education across various disciplines. Nonetheless, there is still a gap between the ability of technology infrastructure in institution or studio environment and its practicality in the studio learning.

Contributions and Benefits of Study

The primary contribution of this study is a review of the literature on studio-based learning's use of technology in practice. By connecting and relating between each theme in the study, it will contribute to the improvement of how personalized digital technologies can empower students to take an active role in designing their learning experiences in studio-based setting. Future studies will be investigating approaches that promote self-directed student learning, while leveraging digital tools to support personalized learning. Nonetheless, current education design and structure need to better connect with the digital technology world by adding online components in the learning systems to improve studio learning effectiveness. Blended learning platforms have shown some positive results in introducing digital technology to adapt the preferences of students. Therefore, the post-pandemic situation also demands the shift learning that brings and moving toward the education 5.0. Furthermore, this thematic review study contributes to informing new Pedagogical Approaches. It is showed in the findings of the study can inform pedagogical approaches in studio-based learning. By understanding the challenges and opportunities of the virtual design studio, educators can adapt their teaching methods and instructional strategies to better support student learning and engagement. This can lead to more effective and meaningful learning experiences for students. In addition, this study also provides a new insight into the guiding technology integration in provides guidance for the integration of technology in studio-based learning. It emphasizes the importance of understanding technology adoption trends and tracking emerging technologies. This knowledge can help educators make informed decisions about the selection, implementation, and integration of technology tools and platforms in studio-based education. This study key's contribution is enhancing learning outcomes which are contributes to the effective communication, access to resources, and peer connections can contribute to enhancing learning outcomes in studio-based education. By addressing these factors, educators can create an environment that fosters collaboration, creativity, and critical thinking, ultimately leading to improved student performance and achievement.

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