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Review

McLuhan's Tetrad as a Tool to Interpret the Impact of Online Studio Education on Design Studio Pedagogy

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Abstract: The COVID-19 pandemic has led to a surge in online studio education, which has presented a significant challenge to traditional design studio teaching methods that rely on face-to-face interactions between instructors and students. It is contended that online studio education enhances the accessibility of design studio pedagogy, making it possible for students to learn from anywhere in the world. However, it also challenges the development of tactile skills, which are crucial in design education. Additionally, online studio education can render certain aspects of traditional design studio pedagogy obsolete, while bringing back elements of design history and theory that may have been overlooked in traditional studio teaching. It can also be argued that online studio education has the potential to reverse the traditional power dynamics between instructors and students, resulting in more democratic and collaborative forms of learning that can empower students. As the literature on the effects of online studio education is growing, there is a need to understand how the shift from the material space and its affordances to an online environment affects the core components of an architectural design studio. To understand the effects of this new medium, this research employed Marshall McLuhan's tetradic approach, a hermeneutic tool to perform a critical interpretation of any medium by examining four simultaneous effects: how it enhances a human sense, what it makes obsolete, what forgotten aspect it retrieves, and how it flips into its opposite at its extremes. A literature review was conducted to analyze the effects of online studios from a tetradic framework and identify the major discussions of the impact of online studio education. The methodology involves a two-part literature review. This study specifically focused on peer-reviewed, empirical research published after 2020, and the authors used search terms related to online architectural studios during the pandemic. The process identified 176 records of peer-reviewed empirical studies for further analysis and 20 papers were read and included in the review, defining repeating topics/themes and organized under four categories pertaining to the founding archetypes of an architectural design studio: (a) setting and communication, (b) actors, (c) outputs, and (d) dynamics. This process was followed by organizing the findings and interpreting them within the tetradic framework to develop a comprehensive understanding of the consequences of the online design studio. Overall, this research aims to provide a detailed and nuanced analysis of the impact of online studio education on design studio pedagogy, conceptualizing McLuhan's tetrad as a basis for the analysis, and therefore aiming to enrich our understanding of the post-COVID-19 era of learning architecture by examining the dramatic change in the medium and its effects.

Keywords: architecture education; design studio pedagogy; online design studio education; tetradic analysis; post-COVID-19

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1. Introduction

The aftermath of the global COVID-19 pandemic and the changing course of life in many aspects have brought many questions to mind: how to adapt, how to interact, what to sustain, and where to work. Although the inevitable changes affected almost every

aspect of life globally, the primary impact for professionals was a shift in their conventional media by going online, and the first consequence was shock and anxiety stemming from the difficulties of adaptation to a new medium. Marshall McLuhan's tetrad is useful as a framework for a comprehensive understanding of the media's effects on our daily lives. This framework accentuates the interaction between technology and society, exploring how each affects the other. By closely examining the devices we use and how they mold us, we can better comprehend a medium's influence on our lives.

McLuhan offers a new scheme/a tetrad of properties or effects that describes the operation of not only media but all human processes, artifacts, and creations [1]. According to McLuhan, a tetrad functions as a theoretical device to examine the effects on society of any technology/medium (put another way: a means of explaining the social processes underlying the adoption of a technology/medium) by dividing its effects into four categories and displaying them simultaneously. The tetrad first appeared in print in McLuhan's posthumously published works 'Laws of the Media' (1977) [1] and *The Global Village* (1989) [2].

The tetrad is a concept/metaphor developed by McLuhan to describe the four laws of media, which exist simultaneously and allow the questioner to explore the existence of the emergent media holistically. These laws are not meant to be viewed successively or chronologically but rather as a whole. When applied to any artifact/system/media constructed by human effects, it describes the ways in which media affect society and how society, in turn, affects media simultaneously [2] (p. 16), [3] (p. 2).

As referred to in this paper, the functionality of the tetrad is not based on theoretical grounds, but revolves around four questions based on empirical observation [1] (p. 175), [2] (p. 15):

1. What does the medium enhance, referring to the way in which a new medium enhances or amplifies an existing medium?
2. What does the new medium make obsolete, or in other terms, does the new medium eventually render an existing medium obsolete?
3. What does the medium retrieve that had been obsolesced earlier, referring to how a new medium can bring back something that was previously lost or forgotten?
4. What does the medium reverse or flip into when pushed to extremes, describing how a new medium can eventually be used in a way that is opposite to its original intended purpose?

Visually, a tetrad can be depicted as four diamonds forming an X (Figure 1), with the name of a medium in the center, where the left/right directions reflect the figure/ground association. The two diamonds on the left of a tetrad are the enhancement and retrieval qualities of the medium, both figure qualities. The two diamonds on the right of a tetrad are the obsolescence and reversal, both ground qualities [4]. In McLuhan's theory of media, he borrows the principle of figure/ground relation from Gestalt psychology to explain how a medium models the distinction between form and content. The figure/ground relation highlights a gap in human visual perception that makes us see either the figure/form or ground/content, but not at the same time. This means that we tend to prioritize one over the other, usually the content over the form. By understanding this principle, we can gain a better understanding of how media shapes our perception of the world around us [5] (p. 5).

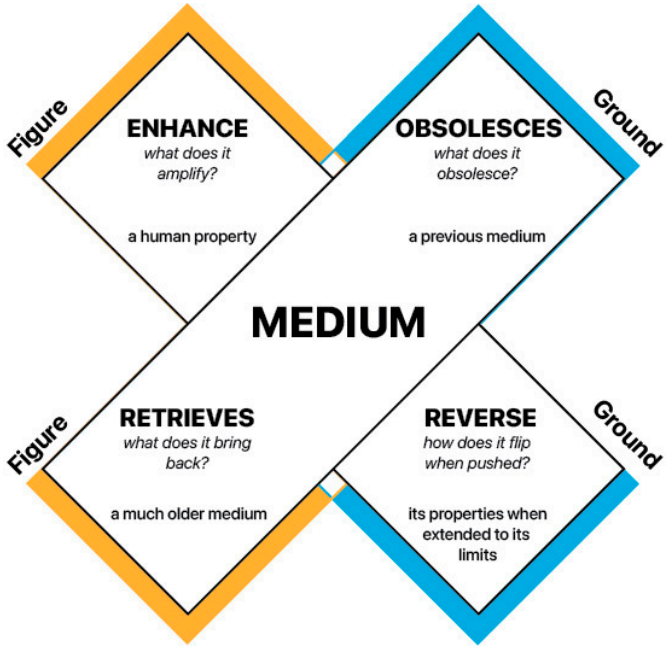

Figure 1. McLuhan's tetrad of the media [2,5].

During and after the COVID-19 pandemic, architectural education has encountered many obstacles, and opportunities for change have arisen. The transition from face-to-face to online teaching highlighted the complexities of the physical medium of architectural education and how it is an integral and resistant component of an established pedagogy. There are continuous investigations into educational theories and concepts with the aim of exploiting these opportunities for transformation, as well as ongoing endeavors to alter the model of architectural education and reorganize its teaching methodology [6–8]. There are studies examining students' evaluations and attitudes toward online design studios during the pandemic, highlighting the uncertainties and the need for additional support and guidance [9,10], providing insights into the future direction of architecture studio education post-COVID-19, and emphasizing the importance of feedback studies, innovation in studio teaching, and a new model for post-pandemic studio education [11]. Additionally, researchers delved into the dynamics of design knowledge construction within contemporary architectural pedagogy, emphasizing the necessity of online and hybrid learning [12], and other researchers explored the potential of virtual design studios in the context of the COVID-19 lockdown, highlighting the emerging potential of this approach [13,14]. The studies collectively underscore the need for innovative approaches, feedback mechanisms, and support systems to enhance the effectiveness of online and hybrid design studio education post-COVID-19. They also highlight the potential of virtual design studios and the importance of sustainable education in addressing the challenges brought about by the pandemic. It is crucial to point out that these research themes rise from the emergent medium of architectural education. Hence, McLuhan's approach to understanding media proves a useful tool for looking into the current context of "online studio education" research to understand the consequences of this new medium, which became compulsory due to the global COVID-19 pandemic.

There appears to be a gap in the literature concerning the critical interpretation of the online studio practices that emerged during the pandemic. These practices incorporated tools and methods developed for ubiquitous communication and collaboration but lacked concrete pedagogical frameworks to support this new medium. Today, most design studio educators may have been trained in a traditional system that emphasizes mostly physical material interactions. As a result, further research is necessary to investigate the instructional models that can effectively incorporate the online setting. This paper is exploratory in nature and aims to develop a holistic understanding of the emerging literature by in-

terpreting the topics and themes following McLuhan's tetradic framework, a hermeneutic tool to critically interpret and analyze reflections on the new online setting of the design studio in the existing literature by organizing the architectural design studio's core components or, in other words, its founding archetypes, to aid future research for developing pedagogical frameworks for this new setting. The study aims to answer the following research questions from a tetradic framework: What are the consequences of shifting to an online setting, as it is a shift from an acoustic to a visual space? How were the main actors of the studio and their roles affected by this shift? Did the outputs of the studio change within the compulsory integration of digital medium tools? How were the communication and collaboration dynamics impacted by the new setting?

The paper is structured into five main parts: (1) Materials and Methods, (2) Architectural Design Studio as a Pedagogical Setting (3) The Online Studio from a Tetradic Framework, (4) Limitations, and (5) Discussion. The structure of the paper follows a logical progression, starting with the Materials and Methods Section, which involves a two-stage investigation. A literature review is conducted in the first stage using specific search keywords and inclusion/exclusion criteria. Relevant papers are identified and categorized based on their topics/themes. In the second stage, data extraction is performed, which organizes the extracted data into categories related to the founding archetypes of the design studio. The paper then introduces Marshall McLuhan's tetradic approach as a framework for analyzing the effects of online studio education. It discusses the different categories of the tetrad and how online studio education enhances accessibility, challenges traditional design pedagogy, and brings back elements of design history and theory. The extracted data are then analyzed and used to apply McLuhan's tetradic framework to understand the consequences of the online design studio. The paper concludes by discussing the implications of the findings and the potential for online design studios to transform architectural education, emphasizing the need for innovative approaches, feedback mechanisms, and support systems.

2. Materials and Methods

This study was anchored in a systematic research framework designed to interrogate the interplay between architectural design studio pedagogy and the physicality of studio spaces, with a particular focus on disruptions caused by the COVID-19 pandemic. Recognizing the foundational archetypes of this pedagogy—setting, actors, outputs, and dynamics—the research poses a critical question: How has the shift to an online architectural design studio milieu, necessitated by the pandemic, influenced these archetypes? Furthermore, what substantive effects can be discerned through the application of a tetradic approach?

The research framework was operationalized through a methodical two-stage literature review (see Figure 2). The initial stage harnessed a systematic methodology that began with the formulation of targeted search keywords. These terms were chosen to capture the essence of the pandemic's impact on architectural education: "architecture", "online studio", "COVID", and "post-COVID". A comprehensive search through "Scite", a smart citation index, set the groundwork for an expansive literature snowballing process, refining the initial set of 9 seminal papers to a significant corpus of 176 related works.

Upon the removal of duplicates, non-English entries, and pre-2020 studies, the remaining 119 papers underwent screening. This phase was guided by stringent inclusion and exclusion criteria, leading to the retrieval of 40 full papers for in-depth analysis. The criteria were: focus on empirical research from architectural design studios, written in English, and published post-2020, ensuring contemporaneity and relevance.

The second stage of the review tried to elevate the analytical rigor, employing "Elicit", a sophisticated tool capable of extracting and categorizing data from the selected papers. Two pivotal categories emerged from the software: (a) topics/themes and (b) main findings. These categories, supplemented with supporting quotations, were documented in Table 1. The reinstitution of the inclusion and exclusion criteria refined the pool to 20 papers. These studies were scrutinized across the foundational archetypes—setting and communi-

cation; actors; outputs; and dynamics, as delineated in Table 2. Through this methodology, the paper aimed to ground its reflections in the concrete evidence of shifts in setting and communication, transformations among actors, evolution in outputs, and new dynamics within the pedagogical process. Each reflective assertion was paired with corresponding research, bolstered by thematic analysis, and cross-referenced with the original empirical studies, which are systematically cataloged in Table 2.

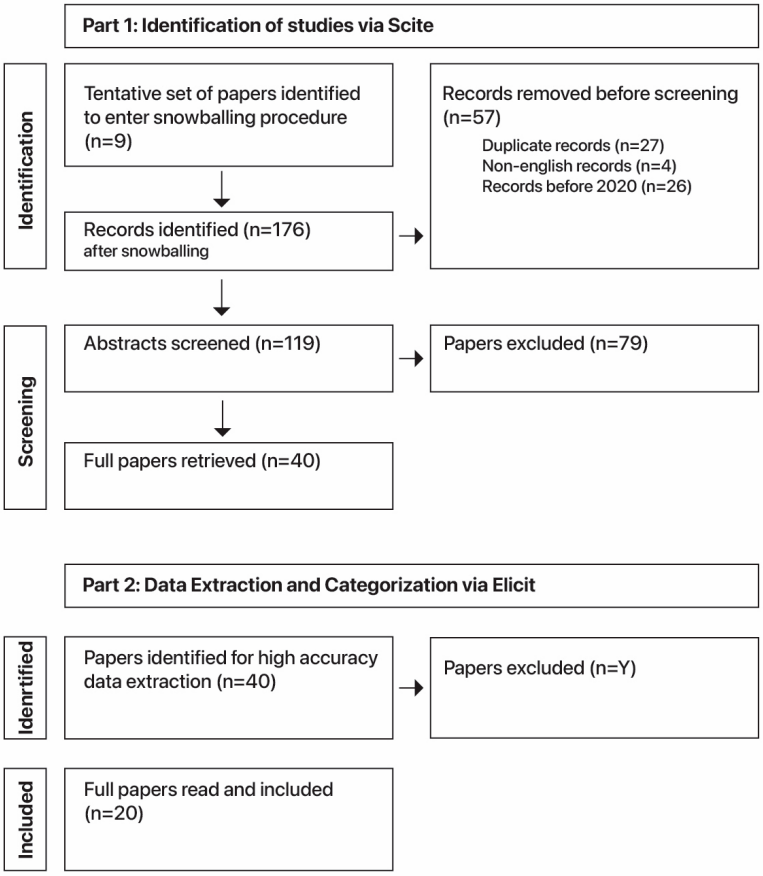

Figure 2. Review process diagram.

Table 1. Extracted data from the full papers categorized under topics/themes and their supporting quotations and findings.

Authors/Paper	Topic/Themes	Supporting Quotations and Findings
Estrina et al. [15]	feedback	There was a problem with effectively communicating and providing feedback, which could be due to various factors, such as a lack of clarity, inadequate channels of communication, or a breakdown in the feedback loop.
	student participation peer learning	Insufficient involvement of the students. Social connectivity decreased.
	design review and evaluation asynchronous access	The students preferred virtual juries. Recordings allowed for in-depth learning.
	digital tool proficiency	The lack of proficiency and efficiency in using digital technology was an issue.

Table 1. *Cont.*

Authors/Paper	Topic/Themes	Supporting Quotations and Findings
Maani et al. [16]	feedback	The instructors' feedback was not as frequent or sufficient as expected, resulting in low satisfaction rates.
	student autonomy	The learners demonstrated a higher level of self-reliance in their learning and took a more accountable approach toward making design choices.
Komarzynska-Swiesciak et al. [17]	virtual setting affordances	The students expressed high levels of satisfaction in relation to their time management, design, and presentation skills.
	delivery methods and tools	The available tools and methods necessitated a redefinition of the instructions.
Hassanpour [18]	student autonomy	It was possible for students to take on a more proactive approach in transferring the knowledge they have gained to making decisions.
	student participation	An educational culture that was not only focused on students but also directed by them, leading to a more integrated and participatory learning experience.
	learning environment	Online education platforms faced challenges in maintaining the same bottom-up approach to education as on-site education due to its intuitive nature.
Murray et al. [19]	delivery methods and toolsengagement	There was not any decrease in user engagement when utilizing a mixture of software platforms.
	delivery methods and tools	There was a requirement to reassess the structures and procedures of the architectural design studio as the distribution of FTF, hybrid, and online studios changes.
	peer interaction	The frequency of collaboration between peers diminished.
Alatta et al. [20]	virtual setting affordances asynchronous access	Virtual learning was flexible, efficient, and enjoyable, and could take place anytime and anywhere with the help of technology.
	student autonomy	Students were not passive observers but active participants in the learning process through self-based learning.
	communication	There were difficulties in both hardware and software, obstacles with accessing the internet, and a lack of experience with the virtual environment.
Asadpour [21]	student participation	A low level of satisfaction was observed due to the dominance of the tutor-centered studio rather than being activity-oriented.
	student autonomy	Virtual education made the students to more positively rely on their abilities rather than the tutors' assistance.
	output media	Instead of physical models, digital models were favored.

Table 1. *Cont.*

Authors/Paper	Topic/Themes	Supporting Quotations and Findings
Asadpour [21]	Feedback	Insufficient understanding of the design objectives and feedback of their tutors.
	communication	Access to technology and internet turned out to be a major issue.
	tutor roles	Conventional roles of tutors as presenters or educators changed into counselors and facilitators.
Ceylan et al. [9]	output media	The most significant benefit of online studios was the use of digital tools for advanced visualization and representation.
	delivery methods and tools	The conventional and emerging education technologies needed to be merged.
Grover and Wright [22]	physical design studio	Teaching in the physical design studio was considered integral to architectural education by the students and staff.
	peer learning	Peer learning and support networks were particularly negatively affected by the closure of design studios.
	communication	The quality of student and staff interactions was compromised.
Smith et al. [23].	design reviews and evaluation	The hierarchical structure of virtual reviews was different from that which occurred in the physical studio, making it closer to becoming a student-oriented learning process.
	peer interaction	Tutors to focus on the social aspects of learning to encourage student interactions and discussion and to introduce strategies that counter feelings of disconnection.
	communication	The dynamics of dialogic interaction arguably became different when occurring in virtual space as opposed to a physical place.
Iranmanesh and Onur [13]	communication and peer learning	Peer learning seemed to be the major part massing from VDS.
	delivery methods and tools	VDS requires both teachers and students to be familiar with a variety of new digital tools.
	design reviews and evaluation	The hierarchical structure of VDS is different from PDS, making it closer to what it is supposed to be, a student-oriented learning process.
	student autonomy	VDS provides an opportunity to increase the self-dependence and research-oriented design approach.
Iranmanesh and Onur [14]	communication	The two-sided communication happened in the physical studio over a table or a board; even a very simple working model is a precise and interactive medium and can convey ideas and comments quickly and intuitively.

Table 1. *Cont.*

Authors/Paper	Topic/Themes	Supporting Quotations and Findings
Iranmanesh and Onur [14]	asynchronous access	Students were able to work on their projects while listening to the critique session and the availability of the recording helped them to pay better attention. Many students also revisited the recording to further improve their work.
	design reviews and evaluation	The virtual jury seemed to empower students to focus on the strengths of their project by providing them more control over what was presented on the screen.
Yu et al. [24]	asynchronous access	Online teaching allowed students to be able to learn anywhere and with relatively flexible scheduling as well.
	delivery methods and tools	Online teaching tools for lecture-based non-studio architecture courses were functioning at suboptimal levels. Instructors often had to manually combine multiple tools to fulfill their needs, which is not ideal. There is a clear demand for better integration of these tools to enhance their interoperability.
Asfour and Alkharoubi [25]	virtual setting affordances asynchronous access	Students could utilize their time more efficiently and had a greater flexibility in online learning and teaching settings.
	peer learning	There was a lack of a collective design studio environment, which resulted in isolation, procrastination, and lower attention levels among students.
	delivery methods and tools	The use of blended learning is a promising strategy in this regard, with the potential to enhance face-to-face design studio courses using interactive online technologies. This requires the development of course materials and specifications to accommodate this strategy, including more group assignments and teamwork.
Zairul et al. [11]	delivery methods and tools	Online technology can be used to improve studio-based learning and architecture along the blended learning spectrum.
	student participation	All the independent and dependent drivers for engaging students, increasing understanding, inspiring, and challenging learners remain unchanged. The current situation also demands the training of lecturers on various tools that can help to engage, challenge, stimulate. and increase the learners' understanding.
İlter [26]	virtual setting affordances asynchronous access	ODS is endorsed for being more egalitarian by its ease of reaching resources, watching recorded lectures and critics, and presenting their work digitally both for critics and juries.

Table 1. *Cont.*

Authors/Paper	Topic/Themes	Supporting Quotations and Findings
İlter [26]	feedback peer learning	The drawbacks of ODS includes a lack of peer learning and limited one-to-one student–instructor interaction.
Alhusban [27]	studio culture	It completely damaged the design studio environment and students' social life and caused them to be lonely and challenged their well-being.
	student participation feedback communication	Online architectural education negatively affected the students' design ability and skills, peer review, students' intended learning outcomes' (ILOs) achievements, the quality of feedback, course contents, interaction mode, and participation.
Ekici et al. [28]	communication peer learning	The students did not find distance education to be as useful as traditional design studios. This was due to a lack of social presence and the inability to share their work with peers as effectively as they could in a physical classroom.
Lotfabadi and Mousavi [29]	student autonomy output media	The virtual studio offered a chance to promote independence and a research-oriented design approach. The students were proficient in digital communication techniques and had acquired the knowledge and abilities needed to be more independent.
Megahed and Hassan [30]	delivery tools and methods student autonomy	The apportionments of blended learning in post-COVID-19 education will grow in a wide range of BL technologies to support the students' development as active and self-directed learners.
	tutor roles	The role of the instructor changes from the teacher as teller to the teacher as curriculum facilitator.

Furthermore, this study was expressly designed to facilitate the application of McLuhan's tetradic framework, which serves as a hermeneutic lens for dissecting the multifaceted transition from physical to virtual spaces in architectural education. McLuhan's framework is instrumental to evaluate the modal shifts within the pedagogy, considering not only the content and curriculum but also the sensory experiences and environmental context that are critical in design education.

The tetradic framework was utilized to examine how the virtual shift enhanced certain aspects of the physical design studio environment. The analysis delved into how online platforms may improve accessibility, allowing for more diversity in participation and potentially leading to a more productive exchange of ideas by overcoming geographical limitations. Next, the investigation shifted to what the virtual studio eliminated, exploring the lost subtleties of in-person mentorship, the reduced sensory involvement with materials, and the potential deterioration of the communal ethos that physical studios cultivate.

The online studio was examined in terms of its ability to revive previously obsolete aspects of architectural education. Such aspects might include a renewed emphasis on theoretical discourse, a revitalization of individual study and reflection, and a renewed focus on digital literacy. The analysis conducted was broad, encompassing not only direct educational processes but also peripheral activities and their educational implications.

Table 2. Findings organized in accordance with the founding archetypes of the design studio.

Archetype	Reference ID	Findings	Mention Qty
Setting	[15,21,22,27,28]	ineffective communication	7
	[15,20,21]	technical difficulties related with the digital environment	3
	[11,18,19,23]	pedagogical challenges and limits of the digital environment	5
	[15,20,24,25]	asynchronous access	5
Actors	[15,21,27]	low level of engagement and participation	4
	[16,18,20,21,29,30]	student autonomy increased	7
	[19,22,25,28]	low level of peer interaction and peer learning	4
	[18,21,30]	tutor roles need to be redefined	3
Output	[13]	proficiency requirement in using digital tools	1
	[17,25,29]	positive effect of virtual setting affordances for skill acquisition	3
	[9,21]	emphasis on digital models	2
Dynamics	[15,16,21,26,27]	low frequency and unclear feedback	5
	[15,23,26]	virtual review sessions allow participation and being student-oriented	5
	[14,15]	recordings allow for in-depth learning	2
	[17,19,24,25]	redefinition of delivery tools and methods	5

The framework considered the potential for a reversal or flip that may occur when the virtual studio is pushed to its limits. This stage of analysis examined how virtual studios had the power to either democratize architectural education significantly or create new disparities and dependencies. It explored the extent to which online learning's prevalence could potentially upend traditional power structures within the classroom, leading to innovative, student-led educational paradigms, or, conversely, result in a depersonalized and transactional educational experience.

By utilizing a tetradic analysis, this study synthesized a comprehensive understanding of the intricate and multifaceted nature of the shift in architectural education. This transition was not a simple dichotomy of "physical versus virtual", but rather a dynamic interplay of enhancement, obsolescence, retrieval, and reversal. This approach allowed for a full picture of the consequences of this shift to emerge. Applying McLuhan's framework facilitated a thorough exploration of the educational transformations that were witnessed during the pandemic.

When constructing Table 1, the data were classified into distinct topics and themes using an integration of inductive and deductive methodologies. The inductive dimension was informed by a grounded theory approach [31], facilitating the natural emergence of patterns, themes, and categories from within the data corpus itself. The analysis that followed was based on the empirical evidence found in the literature review. This ensured that the analysis was well grounded in facts. The themes included in the discussion on digitizing architectural studio education were selected based on their prevalence and relevance across the corpus. Quotations were chosen that exemplified and validated these themes, reflecting the overall story of the data.

Simultaneously, the deductive aspect sought to contextualize these emerging themes within the relevant theoretical discourses pertaining to both architectural pedagogy and digital learning environments. This synchronization ensured that the selected topics were not solely data-driven but also contextually situated within theoretical frameworks, thereby augmenting their value to the scholarly conversation on pedagogical strategies in the field of architecture [32].

In the assembly of Table 2, the study adopted a well-established conceptual framework that isolates the fundamental elements intrinsic to the educational architecture of design studios. These elements—setting and communication, actors, outputs, and dynamics—constitute what is considered the bedrock of the design studio as an educational model. This conception is widely acknowledged within scholarly discourse for its educational import and durability.

The underlying reasons for the selection of these specific archetypes are twofold and can be explicated as follows:

Historical and Pedagogical Significance: This aspect of the analysis recognizes the enduring presence of these archetypes within the tradition of architectural studio-based learning. They collectively encapsulate the educational environment: the setting in which learning unfolds, the educators and learners (actors), the tangible work that is created (outputs), and the ensuing interactive processes (dynamics). These components are integral to the learning process as they foster the reflective practice that Schön [33] emphasizes as central to professional education.

Theoretical Alignment with McLuhan's Tetrad: In accordance with McLuhan's framework, these archetypes are critically examined through the lens of the tetradic effects—enhancement, obsolescence, retrieval, and reversal [34]. This analysis allows for a detailed understanding of how the migration to online educational platforms has reconfigured these foundational pedagogical elements.

The methodological selection and analysis of these archetypes are critical for employing McLuhan's tetradic framework within the study of architectural education. They provide an organized schema through which the intricate dynamics of the design studio can be dissected and understood. This systematic approach yields a comprehensive view of the transformative shifts the transition to online educational environments brought about.

To conclude, the thematic constructs highlighted in Table 1 were chosen to respect both the data as they naturally emerged and the existing theoretical constructs that guide architectural education research. The archetypes presented in Table 2 were carefully selected to showcase their pivotal role in design studio pedagogy and their coherence with McLuhan's method of analysis, assuring a research output that is both rich in empirical evidence and robust in theoretical analysis. The COVID-19 pandemic caused disruptions in architectural education. To explore its evolution, scholars can use grounded theory and theoretical alignment. These frameworks provide a structure for research.

3. Architectural Design Studio as a Pedagogical Setting

Architectural design studios (ADSs) hold a crucial place in architectural education, serving as a fundamental tool for students to integrate and apply their technical and theoretical knowledge attained through various courses. It is essential to note that traditional design studios are mostly considered physical spaces that adhere to a specific pedagogical framework and act as a medium apparatus with its physical conditions. This framework has an extensive history of a learning model called "learning by doing" and "reflecting in/on action", where students actively engage as reflective practitioners to understand the subject matter comprehensively [33,35]. Since it is a unique framework, the studio learning experience mainly differs from other pedagogy models. However, this narrow description of architectural learning has been expanded by its open-plan structure, allowing for formal and informal communication and socialization among all actors connected to a larger context rather than just one-way information transfer from tutor to student [36,37]. Due to the evolving and complex nature of the relationships among its founding archetypes, (1) setting, (2) actors, (3) output, and (4) their dynamics, the studio contains emergent learning potential, and the learner creates subjective meanings and values from their educational experience [38,39].

Following constructivist epistemology, the relationship between collaboration and the physical space is vital to the design studio's framework. Traditional teaching methods and collaborative approaches in design studios rely on being physically present in the same space. The students identified this idea of "studio culture" as prioritizing social experiences over individualism. The teaching methods that shape communication styles and the studio environment, where students engage in ongoing dialogue, greatly influence their learning experiences [40]. Shulman [41] suggests that many higher education educators lack formal teaching training, leading them to emulate the teaching methods they experienced as students. This tendency, known as the "apprenticeship of observation", is

reinforced by the role of the physical studio, which often aligns with the signature pedagogies of a given field and can impede pedagogical innovation. Only the most radical new conditions are sufficient to redirect that pedagogical inertia. Eventually, this inertia was disrupted due to the emergency shift toward online and hybrid learning modes, which resulted in a medium change where individuals were physically isolated/disconnected. This was a concern long before the pandemic among educators and students, as they were concerned about the potential impacts on direct social interactions in the signature pedagogy of studio-based disciplines [42].

As a result of the pandemic, as educators transitioned to online teaching, they found themselves either with a crisis or a unique opportunity to take a step back and reflect on their teaching and learning strategies concerning this mandatory medium change. During this time of reflection, educators faced a dilemma. They could either reassess the design of their courses, experiment with new methods and strategies that they previously did not think about, and adapt to this new medium more effectively. Alternatively, they could approach this new medium as an analogy to the physical studio while holding on to the fundamental assumptions embedded in teaching without any question. Most tutors were able to rely on the online versions of traditional studio practices. Centuries-old techniques, like sketching, diagrams, and exhibits, were applied using online platforms, conducting important ceremonies, assessments, and demonstrations digitally [43].

4. The Online Studio from a Tetradic Framework

4.1. Setting

Classes conducted online or through different media, whether synchronously or asynchronously, have become a significant aspect of the changing education landscape before COVID-19. They can either be integrated into the traditional way of teaching or be a standalone option for those seeking education online. This changing landscape, with the advent of the internet, extended the medium for collaboration and enabled a research field on virtual design studios, looking for ways to increase the capacity of a local/physical design studio by adding a layer of complex social interactions and connective features by involving students and teachers from various universities [44–46]. From an economic perspective, whether conducting virtual design studios is feasible is no longer questioned. However, its adequacy to fulfill the educational outcomes compared to the rich and complex outcomes of a physical studio is still a debate, and it ends up with divided opinions about the potential beneficial impacts of online teaching, such as asynchronous access to the learning material [14,15,20,24,25], and the detrimental impacts of online teaching, such as ineffective communication [15,21,22,27,28], technical difficulties and the learning curve of the new tools of the digital setting [15,20,21], and the pedagogical challenges and limitations of the digital setting [11,13,18,19,23]. It is important to note that, when provided with the option between a fully online or offline ADS, architecture students, despite the common use of "digital native" and their inclination toward online tools, prefer studying design in a face-to-face setting [24,28,47].

To understand this inclination and/or resistance, it is crucial to heed Marshall McLuhan's dictum that changing the medium also alters the message. The expression "the medium is the message" is based on McLuhan's idea that not the medium's content but its characteristics affect the society in which it is active. The media exert these effects by reshaping the ways in which individuals, organizations, and cultures perceive and understand their environments. McLuhan's use of the term "media" encompasses all types of technology and tools, as they are extensions of some human faculty—psychic or physical [48] (p. 26). Hence, his understanding of media encompasses every physical or virtual extension of humans; it allows his tetrad to be applied to any context, in this case, "the online design studio".

The channels we use to communicate have a profound effect on our sensory experience. Every time a new communication technology is introduced, it creates a novel environment that relentlessly acts upon our senses. The media we use to transmit information shape our perception, altering our understanding of the world around us and shaping the

way we interact with it. McLuhan used a spatial metaphor to create the tetrad to perform exegeses on all human artifacts and their effects [49] (p. 65). According to McLuhan, as we shift from the print age to the age of electric media, we move away from the visual space and toward the acoustic space [5]. The acoustic space is a space that does not possess any fixed boundaries and is created by the thing itself, rather than being a space that contains the thing. It is a dynamic space that is constantly in flux and creates its own dimensions in the moment. Unlike the pictorial space, it is not boxed in and has no fixed boundaries [50]. The visual space, on the other hand, represents a uniform, continuous, and connected form of space, which is linear, sequential, static, continuous, and connected (Table 3). The acoustic space allows participation and involvement with information from all directions, while the visual space creates a detachment [34].

Table 3. Qualities organized by spatial association adapted from [49] (p. 75).

Visual	Acoustic
figure	ground
linear	non-linear
sequential	data
asynchronous	synchronous
static	dynamic
container	network
particle	field, resonance

After the shift to online studios, the integration of digital media for communication purposes between instructors and students was compulsory. Various conference meeting software were used for design studio activities. Although the conference meeting software can be categorized under the electric media, the studio experience created within the affordances of these tools eventually turned out to be a visual space where a dialogue between peers was not as effective as it was in a physical studio. A structured studio conversation in an online setting mostly follows an orderly sequence to maintain a clear understanding of what is being spoken as opposed to the chaotic nature of a physical studio. Therefore, it disrupts the multimodal, multidirectional dialogue that exists in a physical design studio due to how this form of communication is organized in this particular medium.

To understand the nature of the effects of a medium on the level of participation and involvement, another concept developed by McLuhan was the distinction between hot and cool media, where "hot" media refers to high-definition media that require minimal audience engagement, such as video, and "cool" media necessitate a greater participation due to their lower definition (the receiver must fill the missing information, not captivated by one sense), such as newspapers [34]. A physical studio as an acoustic space and its cool media, considering its openness to new inputs and different interpretations of all its actors, requires a high level of engagement from its participants. This interpretative opportunity is central to what McLuhan calls a cool medium, offering a chance for real-time co-creation and collaboration [51]. In comparison, the setting of the online studio is constituted of asynchronous (hot) and synchronous (cool) media. One of the dominant interaction methods and media is holding online sessions through video meetings. Online studios have integrated communication tools (hot media), like Zoom, Google Meet, or Microsoft Teams, to enable audio–visual conversations between students and instructors. These tools are used in conjunction with collaborative platforms (cool media), such as Miro or Mural, to facilitate the collaboration and sharing of digital media. When combined, this variety of tools alters the expected engagement characteristics of different media, which have other associations when encountered in a physical setting. Video, essentially a hot media format, is instrumentalized to facilitate the cold communicative acts of real-time interaction [51].

According to Picon, synchronous dialogue on paper media, as a cold media, allows for quick, open-ended, and tactile interaction, whereas videoconferencing, a hot media, has limitations beyond visual presentations. It is important to consider the implications of only

being able to convey information that can be viewed on screens [52]. These implications enhance a dialogue based on graphic annotations and make real-time gestures and mimics obsolete. The asynchrony has been intensified, resulting in a reversal to a spatial condition similar to the spatial mechanism utilized by the École des Beaux-Arts: cells arranged in a corridor, monitored by guardians, for physically and socially isolated students during architectural competitions that could last anywhere from 2 h to 3 months [39]. This represents obsolesced synchronous collaboration and unmediated peer monitoring, and a lower frequency of interaction with students beyond their studio courses and in online studios [19] (Figure 3). This statement highlights the need for educators and students to rethink their communication strategies and adopt new tools and methods that are better suited to the online environment.

Figure 3. McLuhan's tetrad of the media applied to the online setting.

4.2. Actors

A studio consists of two main protagonists among its many actors: (a) student and (b) tutor. Design tutors mainly depend on the dominant pedagogical framework of "reflection-in-action" to describe how students gain architectural knowledge tacitly with the tutor's guidance. Aligning the student with the hidden curriculum [36] (p. 17) is an aspect that summarizes the relationships between all the actors and the behaviors in a studio setting. Within the context of a physical studio, the tutor plays a crucial role in shaping the dynamics between themselves and their students. Through their actions and behaviors, they establish specific identities and pedagogical roles, which can influence the level of autonomy that students are able to exercise. These roles and identities are detailed in Table 4, and they serve as a framework for understanding the complex interactions that occur within the studio environment. Ultimately, the extent to which students are able to take charge of their own learning is heavily influenced by the tutor's approach and the roles they assume.

Table 4. Tutor roles and the effects on autonomy adapted from [53].

Role	Process	Autonomy Level of Student
The master	Mimetic, focusing on the master's practice	Tutor-centered
The atelier coach	Master as a teacher; one-to-one studio conversations	Dependent on the student skill
The reflective practitioner	Reflection-in-action; dependent on master-apprenticeship dynamic; formative	Dependent on the student skill
The critical friend	Reflection in and outside of the action; constructive feedback	Student-centered

Table 4. *Cont.*

Role	Process	Autonomy Level of Student
The liminal servant	Assisting the student's construction of knowledge; involving both the cognitive and social dimensions of learning	Student-centered
The analyst	Forming a mutually beneficial relationship that fosters growth and development, enabling them to eventually engage in creative play independently	Student-centered

The tutor's role in modeling the studio is one of the strongest threads, which involves demonstrating the problems, processes, and possibilities of being and making artifacts in the community of practice, both on at ontological and epistemological levels. By modeling, the teacher provides an opportunity for embodied learning within the studio. This means that students are not mere spectators who watch and mimic the supervisor at work, but rather they become familiar with ways of thinking, feeling, and doing in practice [53], as a part of a learning community. Lave and Wenger [54] proposed that people learn constantly in educational (formal) and real-life settings (informal). They studied how novices can become skilled community members through formal and informal learning. Through educational experiences, each individual transitions toward being a full community member. This model, emphasizing personal identity and contribution to the discipline, expanded the archaic formality of the master–apprentice relationship between the tutor and the student, welcoming informal inductions to the architectural learning process.

The shift toward online design was executed in an emergency, with little thought given to the requisite adaptations in pedagogical approaches that might be necessary for the digital environment. In contrast to the established constructivist learning approaches, with the loss of physical spaces and their affordances, it became apparent that collaborative and communicative learning experiences occur beyond the scope of individual effort [55] because of the low level of engagement and participation observed in the online studio [11,15,21,27], thus disrupting the construction of the roles of the main actors. The traditional methods of learning that rely on the physical space instantly have been replaced by the digital connectedness of a networked learning environment. This new learning environment has altered the construction of the role of tutors, as they are now required to adapt to this new paradigm and integrate technology into their teaching methods [18,21,30]. Dreamson references Siemens' definition of a node as a community and Downes' view that connections between people create a community and a learning society. Therefore, education should enhance the learners' ability to recognize connections among fields, ideas, and concepts and establish connections between nodes. As such, teachers must cultivate and sustain connections to promote ongoing learning [56]. The principles of network learning align with the social theory of Communities of Practice (CoP), discussed in Lave's Situated Learning theory [54]. This mandatory move to online studio settings had the potential to revolutionize design education by embracing connectivity and integrating traditional social components of design studios [56].

However, peer-to-peer interaction and monitoring in online design studios appear to lack a clear structural framework. This is mostly because the primary responsibility for coordinating these activities falls to the tutors [44,57], and the coordinating role of the tutor continued to be central to the studio. It was even emphasized with the shift to the online medium where they were expected to frame, facilitate, and coordinate the peer exchange [45]; it was practical for the tutors to favor online tools with centralized control and a repository-like structure [42] (p. 1874). As a result, there is a significant decline in informal peer learning among students in an online environment [13,19,22,25,28] because of the lack of a collective studio environment that is not solely dependent on the tutor's coordination.

The research reveals that utilizing an online studio can lead to a boost in self-reliant learning. This, in turn, encourages a design process that is both independent and research-driven [13,16,18,20,21,29,30]. However, with the lack of a community and no peer feedback,

the tutors encounter students who hold the mistaken belief that they can excel by simply adhering to the instructor's prescribed tasks since they are the only actor that scaffolds the student's engagement with the learning process. The need for prescriptions was enhanced in the online studio because of the need to facilitate online communication through formal instructions in a visual space. This mere following of formal instruction is a retrieval of the traditional model of master apprenticeship, which is inadequate for ensuring a successful advancement in architectural studies since it is a surface approach to learning [41,58].

In a digitally connected world, the traditional model of master apprenticeship, in which knowledge and skills are passed down from master to apprentice, may not be practical. This is because the speed at which information can be acquired and skills can be learned through networking is much faster than the time it takes for a master to teach an apprentice. Eventually, this shift faced resistance from the traditional learning methods and tools used in physical studios due to the variety of the roles of studio tutors and students and the repositioning of all those involved [56]. Many design educators focused on delivering the surface structure of the stereotypical design studio pedagogy [21,41] because it can be entailed as a set of dialogues under the instructor's control via the help of basic video communication software, which cannot replicate the diverse and complex medium of the physical design studio. Hence, the idea of the community of practices reversed into isolated individuals, and the multidimensional communication of the studio was obsolesced, and this retrieved the master apprenticeship pedagogy because the tutor ended up as the only actor through whom all the exchanges happen (Figure 4).

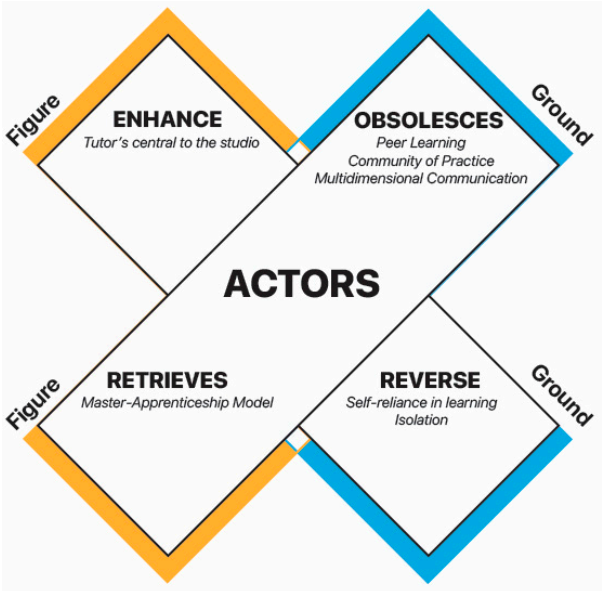

Figure 4. McLuhan's tetrad of the media applied to the actors of the online studio.

4.3. Outputs

Laurillard [59] (p. 60) categorized education media into five principal forms: (1) narrative, (2) interactive, (3) communicative, (4) adaptive, and (5) productive. She also proposed suitable methods and technologies for each medium form (Table 5). Furthermore, she identified five fundamental types of learning activities: apprehending, exploring and investigating, discussing and debating, experimenting, and synthesizing. Laurillard then aligned these learning activities with the forms of media that are most appropriate for supporting them. Specifically, narrative media are best suited for apprehending, interactive media for exploring and investigating, communicative media for discussing and debating, adaptive media for experimenting, and productive media for synthesizing.

Table 5. Education media as five principal forms adapted from [59] (p. 90).

Media Form	Learning Activities	Methods/Technologies
narrative	print/video/ visual materials	apprehending
interactive	web sources/case analysis	exploring, investigating
communicative	online meetings/ collaborative boards	discussing, debating
adaptive	skill development	experimenting
productive	modelling	synthesizing

The online studio significantly improves the students' proficiency in conducting autonomous research and acquiring computer-aided design (CAD) and visualization software skills [17,25,29], in agreement with Laurillard's framework's productive medium aspect, which emphasizes practical skill development and artifact creation. However, as creative individuals, it is essential for the students to consider the affordances and constraints of the materials they work and communicate with as a part of their learning process. The physical materials directly impact the creative process, dictating what is possible and what is not. When working in a physical design studio, students have the opportunity to engage with various materials and tools in a tangible and immersive way. This experience allows the students to fully explore and experiment with their creativity over an extended period of time. By stepping away from digital interfaces and engaging with the physical world, students can tap into a more embodied and sensory approach to making [60]. The act of creating in the studio helps to demonstrate the material aspects of learning. Some tutors suggest that the design of the physical studio space affects the quality of the student's work, indicating that the visual and spatial environment of the studio works in conjunction with the process of creation through shared dialogue [61,62]. With the shift to an online design studio medium, the constraints of the physical materials disappeared, replaced by a mathematical resistance [63], thus obsolescing the tactile aspect of the output media of their design process, where students were required to gain a certain level of proficiency of the digital tools before incorporating them into their design process [13] and were limited by their knowledge of the available tools. For example, novice students who lack experience with digital tools and spatial awareness may struggle with a learning flow that assumes a certain level of proficiency in these areas.

Incorporating modeling and simulation workflows into their design process can prove to be highly advantageous for students. Not only does this approach provide students with valuable data-driven feedback on building performance, but it also enables them to refine their designs in a more efficient manner. By leveraging these advanced tools, students can expand their skills and knowledge [9,21]. This aligns with the adaptive medium aspect of Laurillard's framework [59], which emphasizes the use of technology to adapt learning experiences to individual students' needs. The studies suggest that there has been no noteworthy adverse effect on the standard of assessable design studio submissions [19,24]. Within this shift, the pervasive digital environment pushed the actors to prioritize digital presentation techniques at the expense of hand-drawn and tactile presentations, which supposedly have a transformative effect on the definition of form, functional and formal knowledge characteristics, and models of generative processes [64]. However, replacing the tactile material has an adversarial effect where the generative processes become more linear and sequential for the novice learners since the online studio is more like a charette style of the École des Beaux-Arts as the impact of the shared dialogue on the physical material is reversed into an isolated practice on the digital models (Figure 5).

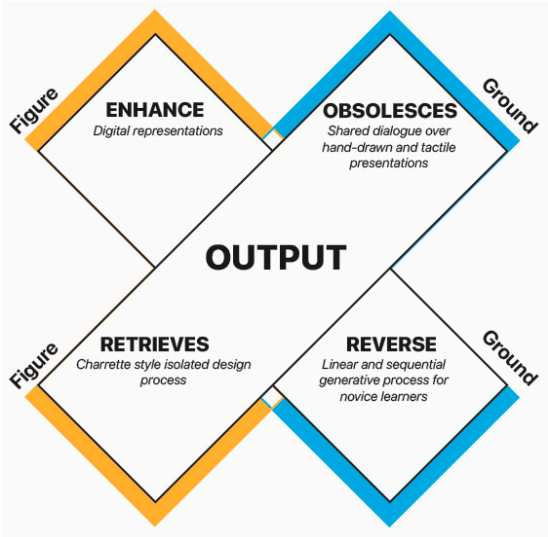

Figure 5. McLuhan's tetrad of the media applied to the output media.

4.4. Dynamics

An architecture studio is an open space that supports various teaching and learning activities, such as lectures, individual meetings, group projects, and various critique methods [65] between its actors through formal and informal communication. With the shift to online education, there were infinite communication channels and types connecting individuals, educators, stakeholders, and specialists. Technology necessitates the functional change and improvement in the learning experience, as opposed to solely replicating offline learning activities and requiring a redefinition of delivery tools and methods [9,17,19,24,25] as blended or hybrid delivery scenarios and enabling information and knowledge sharing across a vast network of resources and people. It is important to note that the tools and techniques of both physical and virtual learning are constantly advancing in conjunction with each other, providing a wider range of knowledge and skill-building opportunities [17].

The studio, being online, now has a chance to be an open system of resources; the more information shared in the studio results in the expansion of the network. This exchange was made easier by converting information and knowledge into small digital modules using different media. This allowed for the efficient utilization of all recorded and documented digital as well as in-class communication [42,57]. It is evident from studies that students are interested in interacting with the class material in a more self-directed manner and would like this interaction to occur within the context of their individual circumstances rather than in the uniform environment of the classroom [19], facilitating the ability of students to transcend the limitations of a physical design studio in the spatiotemporal domain. Students in traditional studio settings are required to engage in discussions with their peers and instructors, all while managing their own design work. The opportunity afforded by the online studio, the recording of the sessions, allows the students to concentrate on either their work or the discussion and do the other at another time without missing any information or comments. This benefit is also emphasized in the studies as the students expressed their appreciation toward the feature of being able to repeatedly view the studio discussions. This feature was perceived as valuable and beneficial to their learning experiences [9,14,15], allowing in-depth learning.

To deliver the teaching and learning activities, learning management systems (such as MOODLE and Blackboard), online conference tools (such as Zoom, Google Hangouts, and MS Teams), and collaboration (such as Miro, Mural, and Jamboard) are deployed for synchronous and asynchronous sessions. One major concern is the lack of a single software tool that integrates all essential teaching functions ending up as an assemblage of different tools. The existing tools do not offer a comprehensive solution, and thus, there is

a need for either better integration between these tools or the development of a new, all-in-one online teaching tool that can effectively fulfill all necessary teaching functions [24]. Integrating all the required platforms together effectively requires a significant amount of manual administrative work and requires additional skills from tutors to frame, organize, and evaluate all the interactions; therefore, the tutor becomes a key factor in facilitating the learning [30].

As an established assessment activity, tutors and students have synchronous experiences through crits, which can be public presentations, juries, or private conversations with a tutor. Design work is often presented visually, making it easier for multiple people to understand and assess the same piece of work simultaneously [66,67]. Despite the aforementioned drawbacks, virtual review sessions offer opportunities for more diverse jury compositions and more student engagement and have been found to be student-centered in several studies [15,23] as they afford students a greater control over the content being reviewed. The hierarchical arrangement of evaluations in virtual settings varies significantly from that in physical studios, which can foster a more substantive feeling of student empowerment [13,14]. Eventually, the online design studio is lauded for its egalitarian nature, as it provides users with easy access to a wealth of resources, including recorded lectures and critiques. Users can also present their work digitally to critics and juries, enhancing the studio's diversity and convenience [26].

Effective online design courses should have instant feedback from tutors, opportunities to exchange ideas with peers, instant peer feedback on work, regular progress checks, and the chance to collaborate with peers beyond the social media [47]. In design studios, critiques serve as the primary mode of feedback between instructors and students, a defining feature that sets architecture studios apart from other educational approaches in varying fields. The student's work undergoes continual influence and response throughout this cycle of discussion [68]. The loss of the acoustic space comes with mixed effects on the feedback mechanics of the design studio. Sequential communication with inadequate channels limits the feedback as a one-to-one student–instructor interaction [30], negatively affecting the feedback loop [15] amongst peers and tutors, becoming less frequent or sufficient than expected and resulting in low satisfaction rates [16]. It becomes imperative that educators allocate additional time and resources toward providing adequate feedback to their students. In cases where an expert is not readily present in the studio for immediate feedback, students find value in viewing other students' work and engage in peer-to-peer comparison activity [69]. However, with the low level of peer interaction and peer learning observed in the online setting, students mostly refer to their own expertise, leading to an increase in their self-reliance (Figure 6).

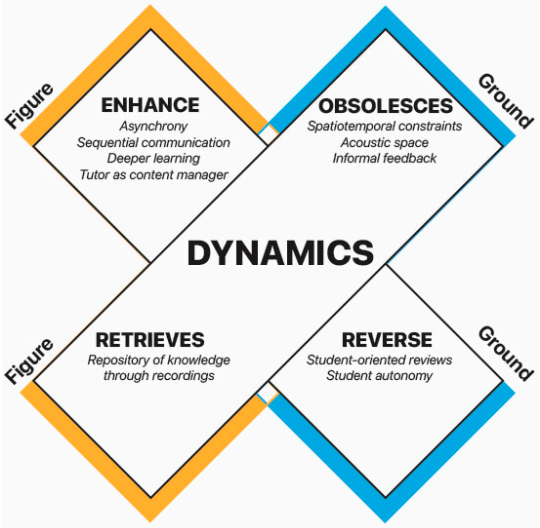

Figure 6. McLuhan's tetrad of the media applied to the dynamics of the design studio.

5. Limitations of the Study and Future Research

For future research, it is suggested that the limitations of this work be addressed by increasing the sample size of the articles reviewed. This will allow for a more robust analysis and a better understanding of the topic. Additionally, it is recommended that a more detailed analysis be conducted that extends beyond the scope of this review. This will help to identify any gaps or inconsistencies in the current literature.

It is important to note that this review relied solely on previously published research and the availability of these studies using the method outlined in the Materials and Methods Section (Section 2). This may have limited the scope of the review and could have led to the exclusion of potentially relevant studies. Therefore, it is crucial for future research to consider alternative methods for identifying relevant studies.

Furthermore, this review's selection and exclusion criteria may not have been appropriate for all studies. As such, it is recommended that the criteria be re-evaluated and that a more comprehensive set of criteria be developed that considers the specific aims and objectives of the research.

Today, online content reaches more users than books and newspapers, and usage habits have evolved in this direction. This simultaneous online interaction has intertwined old and new technologies, with media reaching users in high definition on a single platform. The reasons that McLuhan attributed to cold media, when pushed beyond their limits in the digital age, can heat up and turn back into cold media. Thus, it is now more important to consider the principles (data transfer capacity, high resolution, and appeal to multiple/single senses) with which McLuhan approached media rather than how he categorized the tools. It would be worthwhile to research these aspects of the online setting in future research. McLuhan's ideas on media can be viewed as an evolutionary theory that needs to be re-evaluated with each technological transformation. To categorize whether a medium is hot or cold, it is important to consider the existing media's "data transfer capacity" and determine the level of "participation". This study suggests that this approach could be useful for future research.

Future research may benefit from considering the findings of this paper and exploring in greater detail how the changes in studio teaching that occurred during the lockdown impacted the current studio frameworks after COVID-19. While most of the literature has focused on analyzing the students' reactions to the studio's new online setting, it would also be worthwhile to investigate the educators' perspectives through further research regarding the changes that occurred during and after COVID-19. It will be interesting to observe whether universities have reverted to their pre-COVID-19 teaching methods or whether COVID-19 has permanently altered the landscape of education, either positively or negatively.

6. Discussion

The period spanning from 2020 to 2022 was marked by an unforeseen and prolonged emergency situation, which presented a challenging but highly advantageous testing ground for the digitalization of architectural education. During this time, a large amount of data was collected, which provided valuable insights and lessons that can be used to promote the use of digital tools and platforms in the field of architectural education. This can be conducted alongside physical design studios and involve new approaches, such as flipped classrooms and networked and blended learning strategies. These approaches present both significant challenges and opportunities to traditional design studio teaching methods.

This article, through the lens of McLuhan's tetradic framework, has examined the nuanced implications of this medium shift on architectural pedagogy, especially regarding the essential archetypes of design studio education: setting, actors, outputs, and dynamics. McLuhan's framework for analyzing media effects is well-established [2,34], yet its application to online education, particularly in architecture, is relatively novel. The findings in this study echo the findings of Salama and Burton [6], who noted the adaptability and re-

silience of architectural pedagogy amidst external disruptions, but they also highlight the complexities introduced by the virtual studio setting.

In the transition from material to virtual spaces, the tactile, sensory experience traditionally integral to architectural education was replaced by a more visually dominated interaction, as illustrated in our results. This observation aligns with those of Grover and Wright [22], who reflected on the limitations imposed by the absence of physical materials and their impact on student learning outcomes. However, this study extends this understanding by employing McLuhan's tetrad to dissect these changes, revealing that, while certain communicative dynamics are rendered obsolete, new forms of participation have emerged.

Moreover, our investigation has identified a persistent preference among students for in-person design studios, despite the growing ubiquity of digital tools. This preference resonates with the findings of [28], which reported a similar inclination among architecture students in Turkey. This study contributes to the discourse by elucidating that, while digital tools offer convenience and accessibility, they may not fully replicate the mentorship and collaborative learning of physical studios [10,24].

The role of the tutor, as delineated in Table 4, is further emphasized in this study. The shift to online studios did not diminish the importance of the tutor's role; rather, it underscored their centrality in orchestrating the virtual educational environment [42,56]. The online studio is expected to modify this, considering the digital connectedness of a networked learning environment. However, the tutor ended up being the only point of contact for organizing the emergency studio and maintaining all communication channels, thus consolidating its central role in the studio and retrieving the master apprenticeship model. Another consequence of the online design studio is the obsolescence of multidimensional communication, peer-to-peer interaction, and monitoring, reversing into isolation and self-reliance in learning. These findings diverge from those of other studies [13], which posited a diminished tutor centrality in online studios, suggesting that such differences may be contextually based or indicative of the varying degrees of digital literacy among faculties.

In terms of outputs, it is revealed that students' digital proficiencies were enhanced, and there was an increased focus on self-directed research [17]. However, this came at the expense of the tactile engagement that was previously central to design studios, supporting assertions [64] regarding the potential trade-offs associated with digitalization. This can negatively impact novice learners as the tactile material is replaced with digital models, and the generative process becomes more linear and sequential for nonproficient users of digital tools. It is also argued that the notion of a Beaux-Arts atelier-like online studio setup emerged from the findings, revealing a possible regression in pedagogical approaches [27].

Lastly, the dynamics of studio interaction in an online environment reflected a shift toward a more isolated and autonomous form of learning. This shift aligns with concerns [69] on the potential impacts on peer learning and community-building within the educational setting. This article's findings suggest that, while digital platforms can facilitate knowledge sharing and remove spatiotemporal barriers, they may also necessitate new pedagogical strategies to foster engagement and collaboration effectively. The lack of a single software tool that integrates all essential teaching functions remains a major concern. Tutors played a key role in facilitating learning, to find a way amongst the variety of tools, thus enhancing the role of the tutor as content manager. Virtual review sessions offered opportunities for diverse jury compositions and were more student-oriented as they reversed the traditional power dynamics of a review session. Effective online design courses require instant feedback, peer collaboration, progress checks, and opportunities to exchange ideas with peers. Feedback mechanics became limited due to sequential communication with inadequate channels, negatively affecting the feedback loop among peers and tutors.

The use of online platforms has become crucial for maintaining connections between students and advancing pedagogical methodologies. The transition of architectural pedagogy into the virtual realm has met with mixed reactions, as it has encountered both

successes and challenges. It is evident that the shift in educational media has a significant impact on the fundamental archetypes of the design studio. Therefore, it is important to gain a better understanding of the effects of online design studios and technology integration in architectural education, which can pave the way for curriculum development and further research.

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