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PROGRAMA DE DOUTORAMENTO EM ARQUITECTURA

Traces of gestures:
The resources of freehand drawing in architectural design teaching

Rafael Sousa Santos

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Rafael Sousa Santos. Traces of gestures

Traces of gestures: The resources of freehand drawing in architectural design teaching
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FACULDADE DE ARQUITETURA

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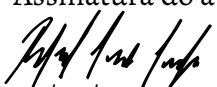

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Traces of Gestures

The Resources of Freehand Drawing in Architectural Design Teaching

Rafael Sousa Santos

This PhD thesis was developed as part of the Doctorate Program in Architecture at the Faculty of Architecture of the University of Porto, within the framework of the European Doctorate Title.

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Scientific supervisors
Clara Pimenta do Vale, University of Porto
Barbara Bogoni, Politecnico di Milano
Poul Henning Kirkegaard, Aarhus University

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Abstract EN

Architectural education has been significantly impacted by the growing use of digital tools in recent decades. Computerized design has become a standard practice, and digital processes are widely used and considered essential in the education of new architects. This has raised questions about the relevance of traditional forms of representation, such as freehand drawing, and their place in architectural education. While conventional freehand drawing remains a requirement in some educational programs, the use of traditional analog methods is disappearing from architecture schools.

This thesis focuses on the relevance of freehand drawing in architectural design teaching by addressing three research questions. The first question seeks to identify the various ways in which freehand drawing is currently used in design education. The second question aims to explore the reasons behind the continued use of freehand drawing in design education despite the rise of digital tools and technologies. The third question aims to identify new ways in which freehand drawing could be incorporated into architectural design education.

The thesis is based on an embedded multi-case design, using qualitative data with supplementary quantitative data. Three schools are used as case studies: the Faculty of Architecture of the University of Porto, the Scuola di Architettura Urbanistica e Ingegneria delle Costruzioni of the Politecnico di Milano, and the Massachusetts Institute of Technology School of Architecture and Planning. Data was collected through naturalistic and participatory observation, individual and group conversations, and document and archival consultation. The collected data was organized into a database and subjected to thematic analysis.

The results demonstrate that freehand drawing continues to be used for representation in the three schools and remains relevant. Even students with no formal drawing training use drawing dynamically during the design process. The significance of freehand drawing is especially evident during critiques, where it serves as the primary mode of interaction between instructors and students in these schools. Lastly, three indications are presented for the future of freehand drawing: the consolidation, transition, and training perspectives.

Keywords

architectural education, design critiques, design studio, forms of representation, freehand drawing

Abstract PT

O ensino da arquitetura tem sido afetado nas últimas décadas pelo crescente uso de ferramentas digitais. Os processos computadorizados tornaram-se uma prática padrão no projeto de arquitetura, e são hoje considerados essenciais na formação de novos arquitetos. No entanto, a digitalização do projeto tem levantado questões sobre a relevância das formas tradicionais de representação, como o desenho à mão livre, e o seu lugar no ensino da arquitetura. Embora o desenho convencional continue a ser um requisito em alguns planos curriculares, temos assistido a um progressivo desaparecimento das escolas de arquitetura.

Com esta tese pretende-se considerar a relevância do desenho no ensino do projeto a partir de três questões de investigação: como o desenho é usado, porquê, e como poderia ser usado. Assim, começando pela descrição das diferentes formas como o desenho é atualmente usado no ensino do projeto, procurar-se-á identificar as razões da sua persistência, para depois se explorarem perspetivas futuras para a utilização do desenho em contexto educacional.

Metodologicamente, a tese segue uma abordagem qualitativa, complementada por dados quantitativos. Três escolas são usadas como casos de estudo: a Faculdade de Arquitetura da Universidade do Porto, a Scuola di Architettura Urbanistica e Ingegneria delle Costruzioni do Politecnico di Milano e a School of Architecture and Planning do Massachusetts Institute of Technology. Os dados foram recolhidos através de observação naturalista e participativa, conversas individuais e em grupo, e consulta de documentos e arquivos. Os dados recolhidos foram organizados numa base de dados e sujeitos a uma análise temática.

Os resultados indicam que o desenho à mão livre não só continua presente nas três escolas, mas que mantém a sua relevância como forma de representação. Mesmo estudantes sem formação em desenho recorrem ao desenho e são capazes de o usar dinamicamente no processo de projeto. No entanto, a relevância do desenho é particularmente evidente nos momentos de critica, onde continua a servir como principal modo de interação entre professores e estudantes nas três escolas. Por fim, são assinaladas três direções para o futuro do desenho no ensino do projeto, a que chamamos consolidação, transição e formação.

Palavras-chave

ensino da arquitetura, critica de projeto, ensino de projeto, formas de representação, desenho à mão livre

Abstract IT

Negli ultimi decenni, l'insegnamento dell'architettura è stato influenzato dal progressivo utilizzo di strumenti digitali. I processi digitali sono diventati una pratica standard nel progetto di architettura e sono oggi considerati essenziali nella formazione dei nuovi architetti. Tuttavia, la digitalizzazione del progetto architettonico ha sollevato interrogativi sul ruolo delle forme tradizionali di rappresentazione, come il disegno a mano libera, e il suo ruolo nell'insegnamento dell'architettura. Nonostante il disegno continui ad essere un requisito presente nei piani di studio di alcune università, è importante rilevare come il suo uso sia in graduale abbandono presso le facoltà d'architettura.

Questa tesi si propone di comprendere la rilevanza del disegno nell'insegnamento del progetto architettonico ponendosi tre quesiti: come viene utilizzato il disegno, perché, e come potrebbe essere utilizzato. Il primo quesito identifica le differenti modalità di insegnamento del disegno oggi. Il secondo ha l'obiettivo di esplorare le ragioni del continuo insegnamento del disegno a mano libera nonostante il dilagante uso di mediatori digitali e nuove tecnologie. Infine, il terzo quesito ha l'obiettivo di identificare nuove modalità di implementazione dell'insegnamento del disegno a mano libera nelle facoltà di architettura.

Dal punto di vista metodologico, la tesi segue un approccio qualitativo, integrato da dati quantitativi. Sono state individuate tre scuole d'architettura come casi studio: la Faculdade de Arquitetura da Universidade do Porto, la Scuola di Architettura Urbanistica e Ingegneria delle Costruzioni del Politecnico di Milano e la School of Architecture and Planning del Massachusetts Institute of Technology. I dati sono stati raccolti mediante osservazione naturalistica e partecipativa, interviste individuali e di gruppo e la consultazione di documenti d'archivio. I dati raccolti sono stati ordinati e organizzati in forma di database e sottoposti ad un'analisi tematica.

I risultati ottenuti indicano come l'utilizzo del disegno a mano libera persista nelle tre scuole, e ne mantenga una certa rilevanza nell'insegnamento. Si è inoltre notato che persino gli studenti senza una formazione nell'uso del disegno ricorrano al suo utilizzo nel processo di progettazione. Comunque, l'importanza del disegno emerge in particolare durante le sessioni di critica, dove continua a fungere da principale modalità di interazione tra insegnanti e studenti nelle tre scuole. Infine, vengono identificate tre direzioni per il futuro del disegno nell'insegnamento del progetto, denominate: consolidamento, transizione e formazione.

Parole chiave

insegnamento dell'architettura, revisioni di progetto, laboratorio di progettazione, forme di rappresentazione, disegno a mano libera

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Chapter 1 Introduction

1.1 Background

1.1.1 Topic

Architectural education has experienced significant changes in recent decades with the growing use of digital tools, particularly in the teaching of architectural design. According to Juzwa and Krotowski (2018), computerized design has become standard practice in architecture over the last three decades. Nowadays, digitally driven processes are widely used in architectural design and considered essential in the education of new architects. In fact, as Leandri (2021) suggests, it sounds unrealistic to conceive of design practices in contemporary studios without digital instruments, such as Computer-Aided Design (CAD) or Building Information Modeling (BIM).

Many countries have adopted regulations that encourage or require the use of BIM in professional contexts. The increasing complexity of contemporary buildings' spatial or technical nature and the need for architects to coordinate with other specialists, particularly those in different engineering fields, make digital tools an indispensable requirement (Taraszkiewicz 2021). The digitization of architectural practice, which has gained momentum in recent years, has raised questions about the relevance of traditional forms of representation, such as freehand drawing, and their place in today's architectural education (Yossef and Salama 2013).

However, according to the last UNESCO-UIA Chapter on Architectural Education (2023), in addition to receiving comprehensive training on digital media in all aspects of education, especially in design, students should also continue to develop their conventional drawing skills as a requirement for their architectural training. The objectives of architectural education, as also described in the UNESCO-UIA (2023 and 2017) report, include skills such as the ability to act and communicate ideas through collaboration, discourse, numbers, writing, drawing, and modeling, and the ability to use manual, electronic, graphic, and model-making capabilities to explore, develop, define, and communicate a design proposal.

It has been noted by several authors that freehand drawing is still recognized as a critical component of architectural education and design teaching (Akdag 2018; Alipour and Faizi 2016; Eren and Yılmaz 2022; Juzwa and Krotowski 2018; Leandri 2021; Nicolau et al. 2018; Soygenis et al. 2010; Yossef and Salama 2013). It is an important propaedeutic to training with digital tools (Eren and Yılmaz 2022), but also a relevant complement to computer-

based methods, with unique and fundamental qualities that cannot be substituted in certain aspects (Nicolau et al. 2018).

The significance of freehand drawing is frequently highlighted in the initial stages of design (Purcell and Gero 1998). Conceptual development requires exploring alternative solutions that are challenging to execute digitally but straightforward to work with manually (Juzwa and Krotowski 2018). In the context of rapidly changing thoughts and visions, freehand drawing offers a clear advantage over digital tools (Putra et al. 2022). Freehand drawing is also particularly advantageous during design critiques, enabling quick and precise exchange of ideas, even in the most advanced stages of design, including technical aspects, as a complement to verbal communication (Nováková et al. 2011).

The primary aim of this research is to examine the role and significance of freehand drawing in design education while critically evaluating its current use. By conducting this study, we aim to provide valuable insights into the future of freehand drawing in design teaching and propose effective research directions. In the upcoming sections of this introduction, we will provide an overview of the scope and focus of our research, which will detail our object of study. Following that, we will present three research questions that our study aims to answer. Additionally, we will conduct a systematic literature review to identify existing viewpoints, research gaps, and areas requiring further examination.

1.1.2 Relevance

As previously noted, freehand drawing continues to be recognized as a relevant skill in architectural education. Both the UNESCO-UIA charter and several authors of recent publications underscore the significance of freehand drawing and still consider it necessary for students to master. However, the prevalence and growing importance attributed to digital tools, whether through the new design opportunities they bring or the influence of recent professional practices in architecture, have led to a decline in traditional forms of representation in curricula over the past few decades in Western universities (Have and Toorn 2012).

In order to examine the relevance of freehand drawing as a research topic in comparison to other forms of representation, specifically digital, we conducted a bibliometric analysis. This research method allows us to study the characteristics and patterns of academic literature and understand the impact and influence of research publications, as described by Donthu et al. (2021).

To carry out the bibliometric analysis, we used the interdisciplinary database Web of Science, as it yielded the most relevant results within our field of interest. We included peer-reviewed publications written in English and published between 2000 and 2022 as our

criteria for inclusion. Two separate searches were conducted, one to investigate the relevance of freehand drawing in architectural design teaching concerning other forms of representation, and the other to broaden our search to architectural design practice.

searches	database	research string	results	refined search	results
first	Web of Science	(((ALL=(architecture)) AND ALL=(design)) AND ALL=(education OR "teaching"))	43,788	"architectural education" OR "architectural teaching"	10,788
second	Web of Science	(ALL=(architecture)) AND ALL=(design)	350,359	"architectural design"	31,331

Table 1. Data search procedures for bibliometric analysis

After conducting a thorough analysis, we realized that research on freehand drawing in the context of architectural design teaching or architectural education, in general terms, is limited. Although the differences in the results of the studies are minor, it is evident that publications on freehand drawing primarily focus on design teaching. A closer examination of the data revealed that freehand drawing consistently ranks among the least researched topics in the field, with digital modeling, manufacturing, and BIM being the most popular subjects. The total number of publications on freehand drawing is 107, which is less than a third of the publications on digital modeling, the most extensively studied topic, with 385 publications.

Interestingly, despite falling behind physical models, freehand drawing shows a steady increase in the number of publications over time. The number of publications on freehand drawing increased from 3 in 2000–2005 to 65 in 2016–2022, indicating sustained interest and ongoing research in this form of representation as a design tool. Digital drawing also exhibits a similar trend to freehand drawing, with a relatively low number of publications but a consistent increase over time. This trend may suggest that researchers are interested in exploring the relationship between conventional and digital tools in design, which could lead to new insights and applications in the field.

rank	topics	2000-2005	2006-2010	2011-2015	2016-2022	total
1	digital model	13	39	100	233	385
2	manufacturing	10	35	112	175	332
3	BIM	0	15	92	224	331
4	prototype	21	35	84	172	312
5	artificial intelligence	36	27	29	193	285
6	CAD	12	27	71	96	206
7	augmented reality	1	3	39	130	173
8	3D model	1	11	57	101	170
9	physical model	0	16	57	95	168
10	parametric model	0	6	50	86	142
11	freehand drawing	3	12	27	65	107
12	digital drawing	2	8	22	43	75
13	generative model	0	7	19	42	68
14	digital rendering	4	7	18	28	57
15	CAM	0	4	17	27	48

Table 2. First search on architectural design teaching

rank	topics	2000-2005	2006-2010	2011-2015	2016-2022	total
1	manufacturing	30	83	251	575	939
2	prototype	101	144	229	425	899
3	BIM	0	38	191	619	848
4	digital model	39	72	218	444	773
5	artificial intelligence	55	61	70	310	496
6	CAD	57	75	158	197	487
7	physical model	18	50	136	251	455
8	3d models	15	40	108	290	453
9	parametric model	5	20	110	256	391
10	augmented reality	4	8	64	152	228
11	freehand drawing	18	25	50	82	175
12	generative model	6	18	46	88	158
13	digital drawing	5	15	46	77	143
14	digital rendering	12	19	38	62	131
15	CAM	7	14	38	45	104

Table 3. Second search on architectural design

Regarding the second search, which explores the importance of freehand drawing in architectural design, it is apparent that the sample size of publications is significantly larger than the previous one. However, despite this increase, the difference in the number of publications related to freehand drawing is not statistically significant. Therefore, it can be inferred that research on this topic primarily falls within the scope of architectural education.

Moreover, the search reveals that the number of publications related to freehand drawing has consistently been lower than other design topics between the years 2000 and 2022. In total, only 175 publications relate to freehand drawing, which is approximately a fifth of the most popular topic, manufacturing, which has 939 publications. Freehand drawing falls outside the top ten topics with the most publications in both searches. Additionally, physical models outperform freehand drawing in this regard.

Considering the two tables, we can see that freehand drawing has consistently had the lowest number of publications in both Architectural Design and Design Teaching searches. This trend has been observed throughout the years 2000–2022, with freehand drawing ranking below the tenth position when compared to other topics. Despite the relatively low number of publications, it is worth noting that the interest in freehand drawing has not entirely waned over the years.

We can then verify that freehand drawing has not been one of the most prominent research areas in recent times. Instead, research has been primarily focused on digital tools, manufacturing and prototyping, and even artificial intelligence. Interestingly, physical models have also received more attention than freehand drawing, with higher values in both tables. Considering these findings, we will conduct a systematic literature review (see 1.4 Review) to provide a detailed overview of the recent research trends and insights into freehand drawing.

1.1.3 Exchanges

As will be discussed further, this research is based on a set of case studies, specifically, a set of design studios and other courses that were observed at the Faculty of Architecture of the University of Porto (FAUP), Politecnico di Milano (POLIMI), and the Massachusetts Institute of Technology (MIT). Two research mobility periods were undertaken during the development of this research. The first was conducted at POLIMI, under the supervision of Professor Barbara Bogoni, for a total of nine months, funded by a scholarship from the Fundação para a Ciência e a Tecnologia (FCT). The second period was undertaken at MIT, under the supervision of Professor Mark Jarzombek, for a duration of six months, funded by a scholarship from the Fulbright program.

The first research mobility period took place following a preliminary visit to the Campus Territoriale di Mantova of POLIMI and was divided into three phases. The first phase occurred between November 2019 and February 2020 and involved systematic observation of architectural design courses, as well as conversations with instructors and students, both on the Mantua campus and at the headquarters in Milan. However, the fieldwork had to be interrupted due to the Covid-19 pandemic and the institution's closure of in-person classes.

Some courses continued to be observed remotely, but the fieldwork was only resumed in May 2021 and lasted until July 2021. During this second phase, in addition to observing courses, the candidate also collaborated as a teaching assistant in the *Architectural Design in Historical Context Studio*, coordinated by Professor Luigi Spinelli and Professor Barbara Bogoni. The final phase occurred between October 2021 and February 2022, during which the candidate exclusively collaborated on the *Laboratorio di Progettazione Architettonica 3*, coordinated by Professor Barbara Bogoni.

The second research mobility period took place at MIT between March and September 2022. During this period, the candidate observed architectural design courses, as well as other courses related to representation, and conducted conversations with instructors and students, following the same methodological approach as the other two case studies. In addition to collecting data through fieldwork, there was an opportunity to begin the overall analysis of the three case studies and to discuss some of the findings with instructors and researchers at the institution. Simultaneously, a study was developed on the drawings made by MIT students between 1873 and 1968, supervised by Professor Mark Jarzombek, which proved to be a very relevant complementary insight for the research (see 5.5 Drawing as a historical record).

Overall, these research mobility periods allowed for a thorough comprehension of the teaching and learning practices at different institutions, providing valuable insights for the analysis and conclusions of the research. The interruptions due to the pandemic demonstrate the importance of flexibility and adaptability in research methodology. Additionally, the collaboration in teaching allowed for a deeper immersion in the pedagogical practices of each institution, which was valuable for the analysis and comparison of the case studies.

1.2 Object

1.2.1 Design teaching

Self and Goldschmidt (2018) define architectural design as the process of transforming an existing situation into a preferential one. As Nelson and Stolterman (2012) assert, the designer's purpose is not to identify a universal truth or "the right solution," but rather the most appropriate alternative for an existing situation. In this sense, Goldschmidt (1991) proposes an understanding of design not only as a problem-solving process but also as a problem-setting process.

Whether as recognition or transformation, the entity to which the designer reacts is made up of physical properties—mostly complex sets of properties—and cannot, therefore, be solved only in the abstract or mental dimension (Self and Goldschmidt 2018). Thus, both in

the attempt to formulate the problem and in the search for potential solutions, the designer needs to resort to external representations (Goldschmidt 1991).

Visser (2006) proposes a definition for the designer's activity as the production of representations, external and internal, individual or shared, where the modalities are verbal, graphic, or gestural. In line with this idea, Milovanovic (2019) highlights that the design process is developed in the interaction between external and internal or mental representations. However, it is important to consider that the relationship between external and internal representations is not univocal; that is, an external representation is not the externalization of a preconceived idea in the designer's mind. As Goldschmidt (1991) argues, the production of external representations is itself part of the cognitive design process: the designer thinks through representation.

There seem to be two major aspects to consider in the relationship between the designer and the external representations from a cognitive point of view. First, as Goldschmidt (2017) refers, the designer establishes a dialogue with the representations produced—this perspective is also compatible with Schön's (1992) proposal of designing as a "reflective conversation." Working as visual devices, the generated representations "talk back," returning information that the designer did not put there intentionally or consciously. Second, as stated by Herbert (1988), the emergence of discoveries also occurs in the physical act of representing itself. When trying to express internal representations, the designer is forced to build a specific organization of the elements.

Design also occupies a central position in architectural education. The purpose of the design studio in the architecture course is that the student learns to design, as stated by Gero and Milovanovic (2020), developing skills in the interpretation of problems and in the evaluation of design solutions. The general understanding that appears in the literature is that the student learns to design by doing, that is, by carrying out an architectural design (Milovanovic 2019; Schön 1983; Visser 2006).

Schön (1983) defines the design studio didactics as a process of individual and collective learning by doing, influenced and guided by the feedback of a practitioner. Thus, what happens in the design studio is a kind of simulation of professional practice in an architecture studio or *atelier*—the instructor can be seen as the project manager, the class as co-workers, and the exercise brief as an order for a real design. As Schön (1983) argues, learning to design comes as the synthesis of a global experience, where students need to give meaning to their design experience, that isto assign a pedagogical meaning to their activity in the design studio.

1.2.2 Design critiques

During the "controlled self-training" path of the architecture student, the instructor assumes the role of a tutor or advisor (Milovanovic 2019). The instructor's role, more than helping the student to carry out the exercise and reach a result, involves encouraging them to reflect on their work (Milovanovic 2019). Design critiques or reviews correspond to the key moment of the interaction between instructors and students in design studios (Oh, Ishizaki, Gross, and Yi-Luen Do 2013). Through design critiques, students receive important feedback about the development of their designs. These critiques can take many formats: one-on-one desk critiques involving an instructor and a student, group reviews, peer discussions, pin-ups, and juries (Milovanovic 2019).

Oh et al. (2013) also observed a sequential organization of critiques that can be summarized in the following steps: students present their work, instructors listen and observe, and often they point out potential problems that lead to an open discussion on these themes. Goldschmidt et al. (2010) propose the organization of instructors' critiques in eight categories: an analysis of the state of design; clarification issues; a proposal for change or improvement; a previous design reference; an explanation of design issues, a theory, a principle, or a norm; statements regarding representation or methodology; encouragement; and identifying an error in design.

However, for the critiques to acquire pedagogical quality, some aspects must be considered. On the one hand, instructors need to build constructive criticism and be clear about their objectives (Milovanovic 2019). This is important for the student, so that they do not understand the critique as a mere personal opinion—fundamentally subjective—or a personal judgment, but as the vision of an experienced professional (Milovanovic 2019). On the other hand, as Schön (1987) argues, instructors must encourage students to accept the experimental aspect of the exercises in the design studio, to avoid them being stuck due to the risk of failing. Students who take a defensive stance in the design studio tend to be limited in design experimentation, and consequently in possible pedagogical contributions.

In the educational context, the role of representation also acquires a new complexity and importance. As Milovanovic (2019, 27) argues, the set of external representations produced by the student "is a key element in the pedagogical situation of design critiques," since the interaction between instructors and students is channeled through these.

What happens is that the student's external representations, in addition to serving as a means of design, also serve as a record of the mental path taken, and above all as a support for discussion and collaboration between them, as a "trading platform," which Milovanovic (2019) refers to as the "representational ecosystem." The concept of "representational ecosystem" is proposed by Dorta, Kinayoglu, and Boudhraa (2016) as the set of produced external representations—sketches, diagrams, plans, sections, mock-ups, digital models,

simulations, and animations of the design object—and their interrelationships, functioning as an "environment for the interaction" between the student and the instructor (Milovanovic 2019).

1.2.3 Freehand drawing

According to Van der Lugt (2003), freehand drawing is an unstructured form of representation typically used in the initial or conceptual stages of design. As a cognitive support, Purcell and Gero (1998) underline the importance of less structured forms of representation, in particular freehand drawing, distinguishing them from the "more structured" forms of representation—such as technical representations, produced by hand or digitally. This idea is frequently formulated as "sketching is a cognitive instrument" or simply "sketching is thinking" (Goldschmidt 1989, 1991, 2014, 2017; Herbert 1988; Milovanovic 2019; Milovanovic and Gero 2020; Purcell and Gero 1998; Tversky and Suwa 2009; Williams and Sanchez-Del-Valle 2008).

But what are the characteristics of these less structured forms of representation, such as freehand drawing, that guarantee their effectiveness as an instrument to support design? According to Goldschmidt (1991), especially in the conceptual phases, the form of representation chosen must allow the design process to be fluid and uninterrupted. In this sense, Goldschmidt states five characteristics of a form of representation that can be considered qualities in the design process: speed of production, minimal generation rules, tolerance to ambiguity, inaccuracy and incompletion, transformability and reversibility, and flexible stop-rules. Freehand drawing seems to be the form of representation that brings together most of these characteristics.

Considering the qualities of freehand drawing, Tversky and Suwa (2009) also underline the speed of production, when compared to other forms of representation, such as modeling, the requirement of few cognitive resources or generation rules, as well as ambiguity. To these characteristics-qualities, Tversky and Suwa (2009) also include the possibility of focusing on some aspects without losing the general sense, the possibility of exaggerating, emphasizing, or distorting aspects or elements of the design, and the possibility of acquiring a public nature, even when fulfilling an initial private purpose.

Despite the growing use of digital methods in design teaching, freehand drawing remains a valuable tool for expression, especially during design critiques. According to Sanders and Stappers (2008), drawing enables a more direct and immediate expression of ideas, which can foster effective collaboration and communication between students and instructors. In fact, Cross (2006) refers to the fact that drawing is an essential skill for developing the ability to visualize and communicate abstract concepts, making it a critical component of the

design teaching process. Drawing offers several unique advantages in the design process, including the ability to quickly capture and convey ideas, experiment with different design possibilities, and engage in a more tactile and personal creative experience (Putra et al. 2022).

1.3 Objectives

The objective of this research is to provide an evidence-based understanding of the role of freehand drawing as a form of representation in architectural design education, to recognize its current relevance, and to identify opportunities for improvement in teaching strategies. To achieve this, three main research objectives were defined:

(i) The first objective comprises thorough research on how the literature addresses the significance of freehand drawing in the design process, particularly in design teaching. This involves the synthesis of key concepts, perspectives, and the identification of prominent studies and authors in this field. Both the literature review and the development of a detailed theoretical framework will constitute a knowledge base to support data collection and result interpretation.

(ii) The second objective is to conduct an evidence-based study in three schools. This entails identifying the most suitable research methods to address the research questions and understanding the procedures that ensure the validity and reliability of data collection and analysis. In this study, we will consider contextual aspects of each school's design studios, the design process, and design critiques, with a specific focus on freehand drawing, while also considering its relationship with other forms of representation. This data will be complemented by the results of a set of supplementary studies that concentrate on specific aspects of each school, contributing to a clearer and more informative interpretation.

(iii) The third objective focuses on aligning observational evidence with the existing body of literature to ascertain how the data corroborates or contradicts prevailing insights. Through this cross-analysis, implications for research are deduced, and prospects for both research and the use of freehand drawing in design teaching are highlighted. This examination will serve to advance our understanding of the subject and offer directions for future exploration and pedagogical practice.

1.4 Questions

Considering the role of freehand drawing in architectural design teaching, three research questions have been formulated. Each of these questions has a distinct nature, which will

guide the entire research process in its various dimensions and ensure that the study is systematic and meaningful.

RQ1: How is freehand drawing used in architectural design teaching?
The first research question has a descriptive nature and aims to provide a detailed description of the several ways in which freehand drawing is currently utilized in design education. To achieve this, we will consider the dimensions within the design studio where freehand drawing is present, the stages of the design process with which it is associated, as well as the functions attributed to it by students and instructors.

RQ2: Why is freehand drawing still employed in architectural design teaching?
The second research question is explanatory in nature and seeks to elucidate the reasons behind the continued use of freehand drawing in design education. To do so, we will examine the specific qualities or characteristics associated with freehand drawing in both the design process and design critiques, and how these qualities are promoted, facilitated, or supported.

RQ3: How could freehand drawing be employed in architectural design teaching?
The third and final research question is exploratory and aims to identify new approaches and improvements related to design representations and design instruction, exploring innovative ways in which freehand drawing could enhance design education.

1.5 Review

To provide a comprehensive understanding of how the three research questions (RQ1, RQ2, RQ3) have been addressed, a systematic literature review was conducted. By systematically identifying and evaluating relevant studies, the literature review helped to establish the current state of knowledge on the topic and provided a foundation for the research work. To ensure the reliability and rigor of the review, the methodology outlined by Borrego et al. (2021) was followed. Additionally, Merzdorf et al. (2008) were used as a reference to guide the review process. This systematic literature review does not replace the theoretical framework (see Chapter 2), and it will be revisited in more detail when discussing the results of this research (see Chapter 6). The table with detailed data from this review can be consulted in the appendices section (see Appendix 1).

1.5.1 Sources

Three databases were used, as recommended in the literature (Bramer et al. 2017): Scopus, Web of Science, and ERIC. These databases were selected for their interdisciplinary coverage, with ERIC specializing in education. The search criteria included papers in

scientific journals and conference papers that were peer-reviewed, written in English, and published after the year 2000. One of the challenges encountered in this review was the classification of architecture publications under various subject areas, such as computer science, engineering, social sciences, and arts and humanities.

searches	databases	search strings	results
search 1	Scopus	(TITLE-ABS-KEY (architecture) AND TITLE-ABS-KEY (design) AND TITLE-ABS-KEY (education OR "teaching")) AND PUBYEAR > 1999	10,895
	Web of Science	(((ALL=(architecture)) AND ALL=(design)) AND ALL=(education OR "teaching"))	43,788
	ERIC	architecture AND design AND (education OR "teaching")	1,396
search 2	Scopus	(TITLE-ABS-KEY (architecture) AND TITLE-ABS-KEY (design) AND TITLE-ABS-KEY (education OR "teaching") AND TITLE-ABS-KEY (representation OR "tool*" OR "instrument" OR "modeling")) AND PUBYEAR > 1999	3,579
	Web of Science	(((ALL=(architecture)) AND ALL=(design)) AND ALL=(education OR "teaching")) AND ALL=(representation OR "tool*" OR "instrument" OR "modelling")	8,063
	ERIC	architecture AND design AND (education OR "teaching") AND (representation OR "tool*" OR "instrument" OR "modeling")	299
search 3	Scopus	(TITLE-ABS-KEY (architecture) AND TITLE-ABS-KEY (design) AND TITLE-ABS-KEY (education OR "teaching") AND TITLE-ABS-KEY (representation* OR "tool*" OR "instrument*" OR "modeling") AND TITLE-ABS-KEY (sketching OR "freehand drawing")) AND PUBYEAR > 1999	46
	Web of Science	((((ALL=(architecture)) AND ALL=(design)) AND ALL=(education OR "teaching")) AND ALL=(representation* OR "tool*" OR "instrument*" OR "modeling")) AND ALL=(sketching OR "freehand drawing")	118
	ERIC	architecture AND design AND (education OR "teaching") AND (representation* OR "tool*" OR "instrument*" OR "modeling") AND (sketching OR "freehand drawing")	5

Table 4. Data search procedures for the literature review

To address this, multiple searches were conducted, and specific keywords were identified and combined to generate the most relevant search results. The initial search yielded many publications, making it necessary to refine the search strategy further to identify the most relevant ones. The goal was to identify approximately 150 publications that would provide a manageable number of articles to review, while still maintaining a broad scope of the literature.

1.5.2 Selection

The selection process for identifying relevant publications for inclusion in this systematic literature review was carried out as follows. Initially, duplicates were removed from the 169 articles retrieved from the three databases, resulting in 147 articles. A first selection was made based on reading the abstracts of the remaining articles. This reduced the number to 55 articles. Despite the titles suggesting proximity to the topic under study, the abstracts revealed varying positions. Additionally, articles not pertaining to the area of architectural design were removed. Of the 55 articles, only 36 were available in an open format or through institutional agreement. These 36 articles were then thoroughly read through to make a final selection. In this context, four classifications were defined to categorize the articles.

stages	procedures	count
	initial number or publications	169
	exclusion by duplication	-22
stage 1	exclusion by abstract	-55
	exclusion by lack of access	-56
	number of publications with open access or through institutional agreement	36
	number of publications classified with maximum relevance	3
stage 2	number of publications classified with intermediate relevance	17
	number of publications classified with no relevance, excluded	-16
	number of publications selected for systematic literature review	20
stage 3	number of selected publications that are journal papers	8
	number of selected publications that are conference papers	12

Table 5. Data selection procedures for the literature review

Ultimately, 20 articles were chosen for inclusion in the systematic literature review. Three articles were classified as having maximum relevance, while 17 were considered to have intermediate relevance. These articles primarily consisted of journal papers (n=8) and conference papers (n=12). Given the limited number of articles that directly addressed the specific problem under study, it was necessary to search for indirect references to the research questions within them.

id	authors	title	year	doc type
1	Putra A.M. et al.	The effect of manual sketching on architectural design process in digital era	2022	article
2	Eren E.T., Yılmaz S.	The student attitudes towards digital and conventional drawing methods in environmental design studios and the impact of these techniques on academic achievement in the course	2022	article
3	Leandri G.	Architecture and digital drawing tablets, bringing back human control over HAL	2021	conference paper
4	Taraszkiewicz A.	Freehand drawing versus digital design tools in architectural teaching	2021	article
5	Hsu T.-W. et al.	Design and Initial Evaluation of a VR based Immersive and Interactive Architectural Design Discussion System	2020	conference paper
6	Juzwa N., Krotowski T.	Sketch-Computer-Imagination Reflections on Architecture Education Methodology	2018	conference paper
7	Akdag, SG	Digital sketching in design education	2018	conference paper
8	Nicolau, I. et al.	Teamwork strategies and methods to improve drawing skills for students (case study: university of architecture and urbanism, Timisoara, interior design department)	2018	conference paper
9	Norgaard, M	Can you picture this? Instructions for using sketchnotes to help novices improve their design sketching skills	2017	conference paper
10	Alipour L., Faizi M.	A new strategy to reduce design fixation: The middle sketching stage	2016	conference paper
11	Špaček R. et al.	Sketching and drawing in the new age - the role of sketching and drawing in architectural and technical education	2016	article
12	Yossef M.N.A., Salama H.A.F.	The power of manual sketching in design	2013	article
13	Nováková K. et al.	Towards Improved Architecture Education A Research Framework	2011	conference paper
14	Soygenis S. et al.	Writing as a Tool in Teaching Sketching: Implications for Architectural Design Education	2010	article
15	Domínguez E.R., Roma G.S.	Teaching methodologies based on touch interfaces for the teaching of drawing and architectural projects	2010	article
16	Akalin A., Sezal I.	The Importance of Conceptual and Concrete Modeling in Architectural Design Education	2009	article
17	Dokonal W., Knight M.	Pen or PC?: Is Sketching essential to architectural design?	2006	conference paper
18	Olmos, F	A training model to develop design skills in the virtual design studio	2006	conference paper
19	Senyapili, Burcu; Basa, Yncy	The Shifting Tides of Academe: Oscillation between Hand and Computer in Architectural Education	2006	conference paper
20	Bailey R.	The student, the master, and the computer	2003	conference paper

Table 6. Selected publications for literature review

1.5.3 Results

In this systematic literature review, we analyzed 20 selected articles based on three aspects: (i) the methodology used, including the type of evidence, research design, and methods employed; (ii) the topic, considering the overall research problem, the most commonly used terms, the importance attributed to freehand drawing, and the shared bibliographic references; and (iii) most importantly, how they address the three research questions of this study.

Methodology

A first aspect to note is that, of a total of 20 articles identified for analysis, only 13 provided empirical evidence and were therefore included in the final analysis. Of the 13 articles included, 9 provided clear descriptions of the methodology followed, while 4 were found to be inadequately described. This is a clear indication of a research gap, as there is a lack of systematically collected empirical evidence that can challenge preconceived notions and biases derived from anecdotal evidence.

Regarding the research approach, it was found that 6 out of 13 articles followed a Mixed Methods approach, 5 followed a Qualitative approach, and 2 followed a Quantitative approach. Furthermore, the research design used by 11 out of the 13 articles was experimental, while 2 articles used a case study design. As for data collection and analysis methods, experiments and questionnaires were the two most used methods.

evidence		approach		design		methods		description	
y	13	MIX	6	experimental	11	experiment	11	clear	9
n	7	QUAL	5	case study	2	questionnaire	9	unclear	4
		QUAN	2	n	7	artifact analysis	2	n	7
		n	7			n	7		

Table 7. Methodology used by the literature

Topic

The publications under consideration can be classified into four topic categories. The most frequent topic is the relationship between freehand drawing and digital media (n=9). Following that, there are articles that propose a new approach to teaching drawing (n=6) and articles that explore the potential of digital drawing (n=6). Finally, the last topic is about new approaches to teaching architectural design (n=2).

During the analysis, an issue arose regarding terminology, with several authors using the terms “sketching” and “freehand drawing” interchangeably. This aspect is not discussed in the literature. Although both terms are widely used, “freehand drawing” is the one that appears most frequently.

The importance of freehand drawing in architectural design teaching was considered using a simple scale of: (i) very important; (ii) important; and (iii) neutral. This classification allowed us to recognize the general position of the authors in the sample. Of the 20 articles, 9 considered drawing to be very important, 5 argued that drawing is important but needs to be seen in relation to other forms of representation, while 6 authors expressed a neutral position. Some authors suggested the need for updated drawing methods, such as digital drawing. Gabriela Goldschmidt was the most cited author in the field (n=6), followed by John Gero (n=5), and B. Lawson and S. Fergusson (n=4).

topic categories		terms used		importance of fhd		references used	
both sketching and digital means	9	design	15	very important	9	Goldschmidt G	6
a new approach to teach drawing	6	digital	8	important but	5	Gero J	5
considering digital drawing	3	sketching	7	neutral	6	Lawson B	4
a new approach to teach design	2	drawing	6			Edwards B	3

Table 8. Topics addressed by the literature

Research questions

In conducting the review of the articles, we initially found that none of them explicitly addressed the three research questions outlined in the research. Through a closer and more detailed reading, we conducted a thematic analysis to identify recurring patterns and themes within the articles. This process enabled us to obtain a more comprehensive understanding of the topics under research and revealed valuable insights that could inform our research questions (Table 9).

RQ1		RQ2		RQ3	
part_design process	18	promotes_creativity	13	design rep_manual-digital	7
tool_thinking	16	allows_expression	9	design rep_d-drawing	6
tool_visualization	13	quality_abstraction	6	design tea_students' interest	3
part_teaching	11	quality_several	5	design rep_hyb-drawings	2
tool_communication	9	supports_memory	5	design tea_drawing inte-tool	2
tool_observation	8	allows_perception	4	design tea_VR	1
when_early stages	8	promotes_exploration	4	drawing tea_students' interest	1
tool_problem-solving	5	quality_bodily factors	4	new app_design teaching_VR	1
tool_annotation	4	quality_transformability	4	drawing tea_teamwork	1
tool_documentation	4	quality_speed	4	new app_design teaching	1

Table 9. Insights from literature for research questions

RQ1: How is freehand drawing used in design teaching?

In addressing the question of how freehand drawing is used in design teaching, a consensus is verifiable among the authors regarding its role in the design process. Most of the authors (n=18) consider drawing an integral part of the design process, while also being an essential aspect of the teaching process (n=11). However, there is a noticeable lack of mention of freehand drawing in desk critiques, with only 2 authors referencing it.

Freehand drawing is primarily regarded as a thinking tool (n=16), which helps designers conceptualize and explore ideas. Moreover, drawing is a visualization tool (n=13) that facilitates the communication of design ideas and enables designers to better understand the spatial relationships between elements in a design. Communication is considered a critical aspect of drawing (n=9), as it allows designers to convey their ideas and designs to clients, stakeholders, and other members of a design team. Observation (n=8) is another role of freehand drawing, allowing designers to observe and record details of an object, space, or environment.

When freehand drawing is mentioned, it is commonly associated with the initial stages of design (n=8), but only one article acknowledges that drawing is also used in the more advanced stages of design. In summary, freehand drawing is seen as a crucial tool for designers, with its primary functions being to aid in the thinking process, visualization, communication, and observation of design elements.

RQ2: Why is freehand drawing still used in design teaching?

There is a wide range of arguments regarding the continued use of freehand drawing in design teaching. Through analyzing the available literature, we have identified several key reasons why freehand drawing remains relevant in the field of design education. One of the

most cited reasons for the continued use of freehand drawing is its ability to promote creativity (n=13). Many authors suggest that the freedom and flexibility offered by the act of freehand drawing can lead to the development of unique and innovative ideas that might not be achieved using digital technologies alone. The tactile nature of drawing on paper also allows for a deeper connection between designers and their work, which can further enhance creativity.

In addition to promoting creativity, freehand drawing is also noted to allow expressiveness in design (n=8). The use of a pencil or pen allows the designer to create a range of marks, lines, and textures that can convey emotions, textures, and other intangible aspects of design that may be difficult to achieve through digital tools. Another significant advantage of freehand drawing is its ability to represent abstract concepts effectively (n=6). Many design ideas and concepts are difficult to convey through words or even digital visualizations. However, freehand drawing can offer a more intuitive and fluid representation of these ideas, which can be especially helpful in the early stages of the design process. Another aspect that is raised is the fact that freehand drawing allows interaction (n=6), which is especially important as a complement to verbal communication.

Furthermore, freehand drawing can also support visual memory (n=5). By creating sketches and drawings by hand, designers can more easily remember and recall ideas and concepts. This can be especially useful when working on complex designs that require a lot of iteration and experimentation. Despite not being widely supported in the literature, some authors consider drawing the form of representation that accumulates the most relevant qualities for design (n=5).

RQ3: How can freehand be used in design teaching?

When addressing the question of the relationship between freehand drawing and digital tools in terms of design representation, authors have presented differing viewpoints, with their positions organized into three broad categories. These categories include improvements or new approaches to design representations (n=15), design teaching (n=8), or drawing teaching (n=7). Most authors (n=7) advocate for the improvement or strengthening of the relationship between freehand drawing and digital tools in terms of design representation. Some of these authors see digital drawing as a way to overcome the weaknesses of freehand drawing, while others view it as an inevitable progression.

In addition, a few authors suggest that digital drawing should be integrated into design representations (n=6) as a means of individual student representation, while recognizing the continued importance of conventional freehand drawing. Some authors also propose that digital drawing can play a role in design teaching (n=3), particularly in terms of

interaction between instructors and students (n=2). This suggests a potential substitution or complement to freehand drawing, potentially enriching the overall teaching and learning experience by leveraging the advantages of digital tools.

In conclusion, while there is a lack of consensus among authors on the relationship between freehand drawing and digital tools in terms of design representation, most authors favor the improvement or strengthening of this relationship. Digital drawing can potentially play an important role in design representation and teaching, particularly in terms of individual student representation and enhancing interaction between instructors and students.

1.6 Outline

This thesis is comprised of seven chapters, including the introduction and conclusion.

In Chapter 2, the theoretical framework is developed, consisting of a set of concepts and assumptions that form a theoretical perspective through which the research question and data will be analyzed. The framework provides a way of understanding and interpreting the research problem and how it fits within the larger context of the field of study. This chapter serves as the foundation for the entire research, establishing the theoretical underpinnings that inform the subsequent analysis.

Chapter 3 describes the methodology used in this research, including the criteria used to define the research approach, design, and methods of data collection and analysis. The chapter also outlines the theoretical position adopted by the candidate throughout the research, setting the stage for the subsequent analysis of the data.

Chapter 4 presents the findings of this research, which are based on the results obtained from three case studies. The chapter introduces the three schools that were examined and outlines the general procedures that were used to collect information. The chapter then presents a detailed description of the data collected based on the units of analysis and summarizes the most relevant discoveries.

Chapter 5 considers four studies that complement the previous chapter. The first study concerns the teaching of freehand drawing, the second explores the relationship between teaching drawing and teaching design, the third examines online design teaching during the pandemic, and the fourth inspects the archive of drawings produced by students between the 19th and 20th centuries. This chapter serves to expand on the themes and topics presented in the previous chapter, providing additional context and insights that enrich the overall analysis and discussion.

Chapter 6 discusses the results of this research. The chapter starts by summarizing the key findings and interpreting their relevance and interrelationships. Next, we address the three

research questions, drawing upon the existing literature and relating it to our empirical observations. The implications for research will then be highlighted, as well as future perspectives for the use of freehand drawing in design teaching.

Finally, Chapter 7 presents the conclusion, which highlights the contributions of this research, its limitations, and directions for future research. This chapter serves to summarize the main findings of the research and to suggest avenues for further exploration and inquiry.

Chapter 2 Theoretical framework

2.1 Design and representation

2.2.1 Design as a process

According to Marti Aris (2005), architectural design, or simply design, is a type of knowledge that emerges from action and unfolds through the process of doing. It is not solely derived from pre-established knowledge but instead involves a dialectical process between thought and action that is always open-ended. As Goldschmidt and Self (2018) suggest, designers use knowledge and information from various domains and through any media to inform design. This highlights the interdisciplinary nature of design and the need for designers to have a broad understanding of various subjects and various media.

Lawson begins his seminal book *How Designers Think* (2005) by emphasizing the complexity of approaching design and distinguishing between the concept as both a noun and a verb. It can refer to the final product as well as the process of work followed to create said product. Interestingly, the same distinction can be made when discussing drawing or sketching. Regarding design as a process, which is the topic we intend to address here, Lawson establishes a quite extensive set of characteristics, which we will review in association with the relevant literature.

One characteristic mentioned by the author is that design is a prescriptive activity focused on formulating solutions for a given purpose. It is prescriptive since it implies transforming an existing situation into a preferred one (Self and Goldschmidt 2018). Some specificities in design solutions are noted by Lawson. First, there are countless different solutions to a given design problem. Second, there is no single ideal solution. Third, design solutions are holistic and address multiple problems simultaneously, but at the same time omitting others . Fourth, and this is especially important, design solutions contribute to knowledge in the discipline, with each solution representing a new step in the development of design knowledge.

Another characteristic pointed out by Lawson (2005) is that the design process involves finding, as well as solving, problems. That design is a process of problem-solving is a widely accepted notion in the literature. According to UNESCO-UIA (2023 and 2017), designing is one of the most complex manifestations of human problem-solving, and the design process is based on a problem-solving framework and a systematic approach. However, as Goldschmidt (1991) argues, this idea does not effectively explain the design process, as a

significant part of the designer's work involves defining and interpreting the problem itself, to then find an appropriate solution.

The design process cannot be described as linear or chronological, but rather hierarchical, and therefore, it is better explained as a navigation between design problems and potential solutions interactively (Goldschmidt 2014). On the other hand, Simon (1973) describes the activity of the designer as a solution-focused approach instead of a problem-focused one.

The design problem has very particular characteristics that make it difficult to solve, but as we have seen, it is also difficult to define clearly. The design problem, as Lisboa (1998) asserts, first arises when the achievement of a particular objective is not obvious or immediate. Additionally, Simon (1959) defines design problems as ill-structured, as they lack defined criteria, do not have natural or obvious boundaries, do not allow for all potential solutions to be considered, and have no possibility of determining the mutual changes of the proposed solution. Thus, they depend largely on the subjectivity of the designer.

Another characteristic pointed out by Lawson (2005) is that the design process is virtually endless. There is no clear endpoint to the design process, making it difficult to determine when a design problem has been entirely solved or at least satisfactorily resolved, as Goldschmidt (1992) argues. Therefore, designers need to rely on their judgment and skills to determine when to stop designing, either due to external constraints, such as meeting a deadline, or when the designer recognizes that further iterations are unlikely to yield significant improvements. Even when the process is completed, it is inevitable that some problems will remain unresolved or even unidentified, and therefore, the goal is to arrive at the best possible solution (Goldschmidt 1989).

In line with the previous argument, Goldschmidt (1992) refers to the design process as both progressive and incremental. This is because, as she argues, design solutions do not appear complete at once, although sudden insights can be crucial in conceptualizing problems and solutions. Goldschmidt suggests that solutions are gradually structured, using each phase of their development as a source of feedback that informs the generation of subsequent phases. An original idea is then subjected to a series of transformations before the solution finally emerges as an appropriate response to a given design problem.

According to Lawson (2005), a successful design is typically an integrated response to a set of problems that requires the ability to integrate and combine ideas. However, there is no infallibly correct process for it. Goldschmidt (1989) refers to attempts that have been made to rationalize the design process, such as those by Alexander, Jones, and Lockman, but with little success. The designer's path is non-linear, non-chronological, and not necessarily hierarchical, so there is no logical sequence of decisions that connects them.

In his book, Lawson also explores various design process maps, only to conclude that these are mostly inaccurate and do not help to clarify the phenomenon. As the author states, these maps tend to be both theoretical and prescriptive and seem to have derived more from thinking about what design might be or should be, and less from observation. Therefore, they are characteristically logical and systematic. This is actually a general problem in research in architecture, as also stated in our literature review (see 1.4 Review).

Thus we come to the last characteristic of the design process pointed out by Lawson (2005), which seems to be at the foundation of all the others, and that is the relevance of the subjective and interpretive dimension. As we have seen, whether in defining a given problem or in searching for candidate solutions that respect various technical and legal requirements and are satisfactory to the designer, said solution can only be explained by a criterion of individual sensitivity and judgment.

On the one hand, in the search for design solutions, the literature refers to two fundamental steps: (i) the generation of candidate solutions and (ii) the evaluation of the level of adequacy of these solutions to a given context. Some variations of this model also arise, describing the search for a solution as analysis, synthesis, and evaluation (Taura and Nagai 2010). On the other hand, in the problem-setting process, interpretation is a requirement for accessing appropriate solutions. As Goldschmidt (1989) argues, experimental interpretation is the essence of design, which guides the design process until the designer is satisfied with the solution.

The issue is that in these two facets of the design process, subjective judgment is the fundamental criterion. However, the ability to make judgments in design, as Lawson (2005) states, comes with experience. Therefore, there is work to be done by designers in their own training, as Vaz (2002) calls it, an education for sensitivity. Moreover, as Lawson (2005) believes, it is necessary to consider that the designer does not approach the design process from scratch. The designer carries with them their own motivations, beliefs, values, and attitudes, which influence their choices and actions, thereby aligning more with the profile of an artist than a technician.

2.1.2 Internal and external representations

Considering that the entity the designer reacts to is composed of physical properties, often complex properties, the use of representations is necessary both for formulating the problem and for seeking appropriate solutions (Self and Goldschmidt 2018). This dimension is so important that Visser (2006) proposes a definition of the designer's activity as the production of internal and external representations, using verbal, gestural, or graphic

modalities. Moreover, Milovanovic (2019) states that the design process involves the interaction between external and internal representations.

As emphasized by Visser and Milovanovic, there are two types of representations: internal, those that exist in the mind, and external, recognizable materially or physically. Internal or mental representations are personal to each designer and are based on their interpretations of a design situation or past experiences, or they may be constructed from an external representation. External representations, on the other hand, are produced as part of the design process, either for oneself or for others, and can serve many purposes (Tversky 2015).

External representations are produced before, during, and after the design process (Yu and Gero 2020) and can vary widely in terms of purpose, modality, media used, or level of abstraction (Goldschmidt and Porter 2014). For example, it is common in the literature to associate less structured types of external representations, such as freehand drawing, with the initial phases of the design process due to their characteristics. In later phases of design, more structured types, such as plans, sections, and elevations produced, for example, in CAD software, are common (Purcell and Gero 1998).

An important aspect, as Dorta et al. (2016) point out, is that no single external representation can access and comprehend a design problem comprehensively. Each form of representation has its own advantages and disadvantages and should be weighed according to a specific purpose (Goldschmidt 2017). Therefore, Milovanovic (2019) states that design activity is characterized by an interactive process of reflection supported by navigation between different external representations.

Design involves the manipulation of multiple types of representations at different scales, related to the progress phase of the design process (Milovanovic and Gero 2020). The requirement for a variety of external representation modalities in design arises from the fact that each medium is inherently linked to specific knowledge structures (Oxman 1997) and its characteristics (Dorta et al. 2016). The multiplication of design representations allows the designer to focus on a specific element of the design that appears in a particular type of representation while maintaining their synthetic understanding of the entire design object, bringing a certain efficiency to the design process (Milovanovic and Gero 2020).

For Vistisen (2015), the external representations produced by the designer in the context of the design process can be seen as their concrete production. That is, the representations produced, as multiple forms of articulating the "design construct," are the main outcome of the mental process followed in the designer's work process. This idea presents design as not primarily concerned with the construction of artifacts but with the production of new knowledge—each new design solution is primarily new knowledge (Vistisen 2015).

Lawson (2005) refers to the significant role played by external representations in the design process as related to the separation that exists in design between ideation and the realization or construction of the object, whether it be architectural or not. The architect has long ceased to be the builder and, therefore, needs to use external representations as a means of communicating their ideas and instructions to others who will execute them. Similarly, according to Goldschmidt (1991), the ultimate goal of the design process is to produce external representations of the design entity that are complete and coherent enough to facilitate its construction or the development of visual simulation.

Despite their determining relevance to the designer, as Purcell and Gero (1998) point out, the production of external representations has often been treated as a skill to be learned or even as a manifestation of mastery or virtuosity, whether in relation to traditional forms of representation or digital tools, and not as an integral part of the design process. This limited understanding can lead to a lack of emphasis on the importance of choosing and creating efficient and appropriate types of external representations, which can ultimately hinder the success of the design process (Ginoulhiac 2009).

2.1.3 Visual thinking and communication

In the design process, representations seem to serve two primary functions: visual thinking and visual communication (Vistisen 2015). These two functions are intricately linked and difficult to separate, and it may be more accurate to see them as two sides of the same purpose: to support knowledge construction in the design process by generating new and more sophisticated information than was initially placed in the representation (Vistisen 2015). In fact, several authors use the term "communication" to refer to the designer's dialogue with themselves, which would make this dimension a part of the visual thinking process itself (Schön 1992).

According to Soygenis et al. (2010), there are different forms of thinking explained by researchers, most of whom agree on the existence of two. The first is a verbal form of thinking, considered intellectual, analytical, and rational, while the second, having a visual form, is considered intuitive, non-systematic, and non-logical. It is often noted that designers think visually, meaning that the representations that serve the designer's thinking are not only verbal but also consist of shapes and forms (Goldschmidt and Smolkov 2004), which are more appropriate and more directly accessible to design thinking (Vistisen 2015).

One of the arguments for the importance of representation for thinking has to do with the limitations of the human brain. As noted by Nováková et al. (2011), it is known that the brain has a limited capacity to store chunks of information. The so-called short-term memory, which is fast enough to help humans operate information, has limited resources, and therefore, notes must be taken to solve a complex problem, such as a design problem. Thus,

designers often take visual or graphical notes as an external medium for extending memory, which more or less creates a restriction on the transformation of the vision in the mind to the representation (Nováková et al. 2011). As Tversky (1999) notes, experiments show that designers cannot remember all the design information and at the same time think about alternatives without using external representations, which help designers unload the burden of retaining all relevant information in short-term memory.

Verstijnen et al. (1998) propose that the decision to resort to external representations is often made unconsciously when creative processing is confronted with resource limitations. Thus, it is perceived that external representations are used to compensate for the limitations of internal representations (Goldschmidt and Porter 2014).

There seem to be two main aspects to consider in the cognitive relationship between the designer and external representations. First, as Goldschmidt (2017) argues, the designer engages in a dialogue with the produced representations, following Schön's perspective of design as a reflexive conversation. Schön (1985) states that designers externalize ideas and then, through examination and interaction with the representations, develop the design further. Designers need to see the visual image to make a decision, add a new design idea, or modify the design. Therefore, Schön argues that the design process should be understood as a cyclical process of seeing-moving-seeing.

Designers do not represent images they have in their minds but rather create visual devices that help them induce images of the entity being created (Goldschmidt 1991). External representations, also referred to as visual devices or communicable representations, are particularly useful in certain types of reasoning, allowing direct access to the information contained therein, as well as to dimensions that are not explicit. Smith (1998) states that when visually depicted, ideas are more able to inspire new ones.

Visual imagery-backed reasoning is thought to play a pivotal role in various cognitive tasks, especially in creative behavior, playing a key role in artistic and architectural reasoning (Goldschmidt 2002), but also in scientific thinking and discovery (Milles 1986).

On the other hand, as Herbert (1988) points out, discoveries emerge through the very act of depicting. The procedures required for the designer to externalize an idea or intuition into a coherent representation force them into a process of organization, selection, and hierarchy, which often leads to the unexpected emergence of visuospatial information. Similarly, the use of different forms of external representations, by implying a diversity of viewpoints and scales, leads to a progressive development of an initial idea, the resolution and completion of blank points, and the production of a general coherence of the design.

An important aspect of the role of representation as visual thinking is raised by Vistisen (2015), referring to the studies of Goel (1995), who determined two main problem-solving

operations, which he called lateral or horizontal transformations and vertical transformations. In lateral transformations, design moves occur from one idea to a different one and are also referred to in the literature as exploration operations. Vertical transformations, on the other hand, are movements made from one idea to a more detailed and accurate version of that same idea.

2.2 Design teaching and representation

2.2.1 The design studio

Design is an overly complex and sophisticated skill that needs to be learned and practiced, much like playing a sport or a musical instrument (Lawson 2005). Teaching design has some common characteristics that transcend countries and even design domains (Alves Costa 2007), and the most common model around the world in design education is the design studio (Milovanovic 2019).

Schön (1983) characterizes design studio education as a process of individual and collective learning through practice, guided by feedback from an instructor, usually an experienced practitioner in the field. The design studio is a crucial element of architectural education and should represent the largest and most significant part of the learning process in architecture, as referred to by UNESCO-UIA (2023 and 2017). In the design studio, students mobilize the body of knowledge about architectural design they have received, both within the course and outside the studio (Milovanovic 2019).

The goal of the design studio is for students to acquire design skills, both in problem interpretation and evaluation of design solutions, and to learn to think in a "designerly way" (Milovanovic and Gero 2020, 44).

More specifically, the objectives of education in architectural design indicated by UNESCO-UIA (2023 and 2017) are:

(i) the capacity to engage imagination, think creatively, innovate, and provide design leadership;
(ii) the capacity to gather information, define problems, apply analysis and critical judgment, and formulate strategies for action;
(iii) the capacity to think three-dimensionally in the exploration of design; and
(iv) the capacity to reconcile divergent factors, integrate knowledge, and apply skills in creating a design solution.

The pedagogical methods used to teach design in studios are diverse, such as theoretical sources, workshops, informal discussions, and especially design critiques and juries (Milovanovic and Gero 2020). But in its essence, we can describe the pedagogical method of

the design studio as learning-by-doing, that is, through the realization of a design project by students under the supervision of instructors (Schön 1983; Visser 2006; Milovanovic 2019).

One of the peculiarities of this teaching model is precisely the fact that the object of study, the design itself, cannot be exactly taught (Alves Costa 1991). Unlike a common classroom, theoretical knowledge in design must always be associated with practice or the experience of practice (Şenyapili and Basa 2006). In the design studio, students learn to approach design problems and formulate solutions, rather than acquiring theories and applying them (Lawson 2005).

Regarding this particularity of design teaching, the literature uses expressions such as "active learning" (Eren and Yılmaz 2022), "learning by doing" (Olmos 2006), or "reflection-in-action" (Schön 1992).

Therefore, students need to play a significant role in driving their own learning process, being able to synthesize a comprehensive experience in designing (Schön 1983). Thus, it is the student who needs to attribute meaning and sense to various design experiences that they will have during their education and assign pedagogical significance to them (Vieira 1995). In fact, one of the key ideas of design teaching is the notion of "learning experience," as it is the learners' experiential events that will shape their cognitive structure (Milovanovic 2019).

According to Milovanovic (2019), this learning model echoes constructivist and cognitivist learning approaches, where students are consistently confronted with tasks for which they are not completely prepared, causing an imbalance in their cognitive structures. Once the problem is solved, it leaves traces in the learner's memory that will influence future problem-setting and problem-solving activities. Thus, students acquire expert skills or cognitive strategies applied to "real situations" (Milovanovic 2019, 41).

A learning strategy involves providing students with a learning experience that simulates the professional practice of an architecture firm or office. Milovanovic (2019) refers to the idea that the main instructor can be seen as the project manager, the various students in the class share the same workspace, and the exercise brief serves as a real design project to be developed.

On the other hand, design teaching, like design itself, has an incremental nature. As students progress through the course, they become increasingly autonomous, and the challenges they face become more complex, with more constraints, requirements, legal, or constructive issues (Olmos 2006). As Schön (1981) notes, design skills or notions of thinking architecturally cannot be discretized and learned sequentially but constitute a global experience. Thus, skills and knowledge are acquired without the same conscious effort as in traditional education (Pause 1976).

In the design studio, while students play a crucial and perhaps unique role compared to other classrooms, so do the instructors. Various terms have been used to refer to the design studio educator, which in itself seems to assign them a certain role, ranging from master, user, or moderator (Oh et al. 2013). These terms include teacher (Pause 1976), tutor (Milovanovic 2019), or instructor (Oh et al. 2013).

If the role of the instructor in the design studio is to guide or orient students in their task—that is, to perform a design activity (Milovanovic and Gero 2020)—there is a decisive importance in the instructor-student relationship, as we will see later, as well as the classroom environment (Pause 1976). An appropriate classroom environment is important for students to feel confident and encouraged to experiment and take risks, maximizing their learning experience (Quadros in Pais 2018). It is important that the instructor presents the tasks to the students as educational exercises, not as a form of personal evaluation. The overlap of the academic dimension with the personal and its evaluation can be quite problematic, leading students to limit themselves.

Finally, a relevant point raised by Milovanovic (2019) is the distinction that needs to be made between learning objectives (design) and teaching approach (design education), as they are so intricately linked that they are often confused. In fact, these dimensions frequently appear indistinguishable in the literature.

2.2.2 Design critiques

Design critiques, also known as desk critiques or reviews, are a vital component of the design studio (Oh et al. 2013). They form the basis for the entire design learning experience (UNESCO-UIA 2023) and are the primary way in which design is taught and learned in a design studio (Goldschmidt 2017). During design critiques, instructors and students engage in a conversation where they discuss the strengths and weaknesses of a design, present examples, and sometimes even discuss architectural theory and philosophy.

The primary goal of design critiques is to provide students with valuable constructive feedback on their work (Milovanovic and Gero 2020). They are typically conducted on a weekly basis within the design studio (Oh et al. 2013) and serve to mark the temporality of the design studio and track students' progress throughout the learning period (Milovanovic 2019). During design critiques, students are expected to present and explain their proposals, giving them the opportunity to practice their communication skills, which are essential for their future as designers (Milovanovic and Gero 2020).

Design critiques are a critical moment for the development of students' skills in the interpretation of problems and the evaluation of design solutions, as they may lack experience in conducting the design process (Cross 2004). This lack of experience can lead to

premature fixation on a concept that is not suited to the situation or, on the other hand, excessive exploration of alternatives without being able to understand which ones are relevant (Cross 2004).

The content of critiques is tailored by the instructor to achieve specific pedagogical objectives, which may focus on the design process, design concept, quality of communication, representation, prioritizing creativity and innovation of solutions, or giving more importance to the functional aspects or feasibility of the proposal (Milovanovic 2019).

Goldschmidt et al. (2010) suggest that instructor critiques can be classified into eight categories: (i) analysis of the state of the design, (ii) clarification of issues, (iii) proposals for change or improvement of the proposal, (iv) references to previous design projects, (v) explanations of design issues, theories, principles, or norms, (vi) statements regarding representation or the design process, (vii) student encouragement, and finally, (viii) identification of a design error. In the cases studied by Goldschmidt et al. (2010), most verbalizations focused on explaining an issue, theory, design principle, or standard. The second most frequent type of verbalization was the identification of a design error.

These design critiques can take various formats: one-on-one critiques involving an instructor and a student, group reviews, peer discussions, pin-ups, and juries (Oh et al. 2013). Individual critiques are the moments when students can present their work and receive feedback from instructors, helping them face a specific design problem or overcome a phase in which they are stuck in the design process. Group critiques are also relevant alternatives to individual monitoring because students learn both from critiques of their own work and from the critiques of others (Milovanovic 2019).

Other formats, such as juries, provide students with feedback on their work from a wider panel, often instructors from other design studios, courses, or institutions, or even experienced practitioners, providing an opportunity for students to practice their communication skills. Juries are used to organize the design studio, validate design stages—which used to be called intermediate juries or mid-terms—and assign a rating to the quality of work and its progress (Milovanovic 2019).

Oh et al. (2013) observed a typical sequential organization of critiques, which consists of students presenting their work, instructors listening and observing, and then pointing out potential problems or inconsistencies in the proposal that lead to an open discussion on these issues. Problems can be addressed and explored by instructors during design critiques or simply pointed out, leading the student to reflect on them after the critique and adapt their design proposal accordingly (Schön 1985).

Schön (1985) identifies four types of actions in design critiques: telling (instructors) and listening (students), demonstrating (instructors) and imitating (students). The first set corresponds to the explicit formulation of design knowledge, such as specific instructions to be followed, theories related to design, requirements for external representations, or precedent design references. The second set refers to a specific design situation through an instructor demonstration. These two sets correspond to two different pedagogical situations contained in design critiques, which Schön (1981) refers to as (i) explanations and (ii) demonstrations.

The conversation during design critiques is based on the students' previous productions and their external representations, to which other productions are added during the critique, both by instructors and students (Milovanovic 2019). As Pause (1976) points out, one of the central aspects of the design studio and design critiques is the instructor. The design studio instructor differs from most teachers in two ways. Firstly, because the design studio instructor is often a practitioner, who can function as a role model for students. Secondly, because the common model of teaching and learning in the studio is processed through one-to-one exchanges between them.

Along with this close contact between instructors and students, there is the possibility for the instructor to have a significant impact on students. This is enhanced by the time devoted to the design studio in the curriculum and its consequent curricular relevance. Therefore, what the instructor says and does in the design studio can have effects on students at various levels. Some of the messages are explicit and intentional, while others are not (Pause 1976).

On the other hand, design studio instructors are often professionals without pedagogical training (Milovanovic and Gero 2020). This sometimes raises problems related to verbal exchanges, as instructors from practice comment on students' work based on their practical knowledge and professional experience (Goldschmidt 2010), often without a clear understanding of the sense of critique pedagogy (Dorta et al. 2016).

As Milovanovic (2019) states, for design critiques to acquire pedagogical quality, it is essential that the instructor's criticism considers certain aspects. On the one hand, instructors need to provide constructive criticism and be clear about their objectives. This is important for the student so that they do not perceive it as a mere personal opinion—fundamentally subjective—or even as a personal judgment, but rather as the perspective of an experienced practitioner. The difference between personal opinion and analytical criticism from the instructor, based on their professional expertise, needs to be understood by students to strengthen the pedagogical quality of the critiques.

Drawing a parallel between the relationship of a psychoanalyst and their patients with instructors and students during design critiques, Milovanovic (2019) argues that the

discussion should, at least initially, remain neutral. If difficult criticisms appear too early in the discussion, the student may become defensive, which can compromise the possibilities of creative interaction and the quality of the critiques themselves.

It is important that the relationship generated between instructors and students is one of trust but also comfort, to allow for a productive and constructive discussion about design (Pais 2018). Moreover, as Schön (1987) points out, instructors should encourage students to accept the experimental nature of exercises in the design studio, to prevent them from becoming blocked in the face of the risk of failure.

2.2.3 Design representations

According to Şenyapili and Basa (2006), the role of representation in generating ideas seems to be more important in design education, specifically in design critiques, compared to practice. In fact, expressing, visualizing, and representing design ideas through hand drawing or digital tools has been a fundamental concern in architectural education (Şenyapili and Basa 2006). Eren and Yılmaz (2022) discuss how, in architectural training, teaching primarily focuses on learning visualization techniques to develop visual thinking skills. This is because, as mentioned by Leandri (2021), there is an association between representation and understanding.

In the specific context of design critiques, representation plays a key role. According to Milovanovic (2019), there are four different purposes of design representations during design critiques. First, external representations serve as a means for students to express their design intentions and concepts to instructors. Second, these representations support collaboration, as design critique participants can use them to negotiate, explain concepts, seek solutions, and reflect on a particular idea. Third, these representations serve as design instruments through which students and instructors can propose a general or partial solution to an unresolved design problem by redesigning a plan, a section, or other elements. Fourth, a function of these representations, especially relevant in the context of design education, is that they serve as a record of the student's mental path and design progress, which can help identify difficulties, singularities, or simply be used for evaluation.

This interaction between instructors and students during design critiques, given that it produces effective advances in both identifying the design problem and designing the solution, is sometimes referred to in the literature as collaborative design, co-operative design, or co-design (Dorta et al. 2016). As Milovanovic (2019) points out, for design critiques to make sense and be efficient, there must be a mutual understanding of the design situation between instructors and students, which is mainly processed through external representations and affects individual internal representations. Therefore, the set

of external representations produced by students is a key component of design critiques, functioning as a trading platform or a "representational ecosystem."

The concept of a "representational ecosystem" is proposed by Dorta et al. (2016) as the set of external representations, including sketches, diagrams, plans, sections, elevations, mock-ups, or digital models, and their interrelationships, functioning as an environment for interaction between instructors and students. Tangible design representations, such as technical drawings and mock-ups, are not sufficient to illustrate design, and participants complement them using gestures or sketches (Milovanovic and Gero 2020).

One of the characteristics of the representational ecosystem is hybridity, allowing designers to move back and forth between analog and digital representations, integrating multiple dimensions and types of representations and scales. Another important characteristic of this notion of an ecosystem is the synchronization between all the representations, providing a synthetic and unified perspective of the design project.

As several authors have noted, during design critiques, traditional forms of representation such as freehand drawing or physical models still seem to prevail over digital tools. As stated by Dorta et al. (2016), due to the monolithic approach introduced by generic 3D modeling software, which does not consider the multiplicity of representations or support processes such as abstraction, the current digital paradigm seems to fail to effectively support design critiques. When design critiques take place entirely in a digital medium, the inflexible characteristics of those representations and the difficulty of manipulating and transforming them in real time result in a discussion that is mostly verbal, analytical, and advisory.

Goldschmidt et al. (2010) also refer to significant changes in design critiques since laptops were introduced as everyday tools, questioning their efficiency and pedagogical value. In fact, over the last two decades, criticism has become an essentially verbal activity, restricted to discussions between instructors and students about their work.

Therefore, the conventional workflow of design critiques and the dynamics of the design studio in general have been interrupted by the dissemination and premature introduction of laptops as a substitute for the traditional representational environment for design, in many cases with traumatic results. Thus, Dorta et al. (2016) state that it is necessary to think about a new paradigm that is better integrated with the broader representational environment of the studio, rather than the current digital paradigm.

2.3 Design teaching and freehand drawing

2.3.1 The functions of freehand drawing

As Goldschmidt (1991) points out, freehand drawing or sketching is a common human activity, similar to writing, with artists and designers being among the largest producers of drawings. In fact, in design activities, freehand drawing is often referred to as a thinking tool (Carneiro 1995), similar to writing, considered as a language for designers (Nørgaard 2017; Bilda and Gero 2006). It is also common in the literature that designers "read" their own drawings, which is a way of establishing a conversation with themselves (Soygenis et al. 2010).

The term "sketch" generally refers to a rough or unfinished drawing, and the activity of sketching is to give a brief account or general outline of something (Vistisen 2015). As with design, the dominant position in the literature on freehand drawing tends to be process-oriented, focusing on freehand drawing as an activity rather than as an outcome of the drawing process (Vistisen 2015).

As Garner (2012) notes, the literature on architectural design has attempted to determine the functions of freehand drawing in the design process. It is common, as he observes, for freehand drawing to be presented as a means of communication, a means of design, or a means of analysis. Variants of this categorization of the functions of freehand drawing can be found. Have and Toorn (2012) state that freehand drawing serves communication, perception, and visual thinking. Sanchez-del-Valle (2008) argues that freehand drawing facilitates the procedure of bringing ideas to the surface, backtracking to access ideas later in the design process, and refining ideas.

Vistisen (2015) argues that while freehand drawing can be understood as the first form of activity to create external representations in the design process, the value attributed to it depends on whether freehand drawing is primarily seen as a form of visual thinking or visual communication. That is, using Herbert's (1997) terms, if freehand drawing is used more to produce study drawings of a private nature or presentation drawings of a public nature. Here we see how the functions of freehand drawing are reduced to two fundamental domains.

The dominant perspective in the literature has been to consider freehand drawing as applying visual thinking, allowing the designer to reinterpret the representations of the drawing into new knowledge (Vistisen 2015). The same reading has been made in the context of architectural education, where freehand drawing is mainly seen as a design tool.

Purcell and Gero (1998) discuss how freehand drawing is often associated with the conceptual or initial stages of the design process, as an unstructured form of representation that allows the designer to mediate the process of sense-making between themselves and

the design problem (Vistisen 2015). As the design progresses to more advanced stages, designers resort to more structured forms of representation, such as technical drawings made in hard line or digitally (Purcell and Gero 1998). This is a frequent position in the literature (Milovanovic and Gero 2020).

Interestingly, freehand drawing is also associated with design critiques, primarily used by instructors to follow up with students (Herbert 1988). Since the design process is heavily influenced by feedback and dialogue, the expressive and communicative dimension of drawing is essential for reflection-in-action by the designer and allows a broader community to observe, comment, and review ideas from what is represented (Vistisen 2015).

Goldschmidt (2017) argues that freehand drawing is a way to ensure that the same vision is shared by students and instructors during design critiques, as it functions as a complement to verbal communication but also to other forms of representation. However, again, it is advantageous for both instructors and students to have drawing training and to be aligned in terms of drawing representation. Thus, we see that in the context of architectural education, and particularly in design studios, the communicative or shared dimension of freehand drawing is of foremost importance.

Garner (2012) discusses how freehand drawing, understood as a messy practice, operates at significant moments of exchange, negotiation, and power-brokering in a mixed practice of computer graphics and hand drawing. He refers to freehand drawings as objects with flexible boundaries. He also states that freehand drawings are powerful due to their meta-indexical qualities—their ability to hold ground and negotiation space for both explicit and yet-to-be-made-explicit knowledge, allowing them to be more than the sum of their parts.

Goldschmidt and Porter (2014) suggest that, from a cognitive point of view, freehand drawing is the closest evidence of the designer's mental process that we can access. This is especially important in the context of design education, as it allows instructors to approach the student's mental process and identify their pedagogical situation, as well as their difficulties and particularities.

2.3.2 The particularities of freehand drawing

Designers extensively sketch—from lines, shapes, objects, and indistinct things—until they can read something useful from these drawings. Goldschmidt (1991) refers to this operation as interactive imagery. Moreover, freehand drawings can be made anywhere: on a sheet of paper, a notebook, the back of an envelope, or overlaid on technical drawings, giving them great versatility and autonomy, not requiring any intermediary, as is the case with digital tools (Goldschmidt 1991).

The particular qualities of freehand drawing in the ideation and concept generation process in design have been extensively studied in the literature. Tversky and Suwa (2009) highlight several qualities of freehand drawing as a form of representation, including speed of production, low cognitive resources required, and ambiguity, with the latter being a determining factor for innovation in design (Goel 1995).

The ambiguity of representation in the design process is not a negative characteristic; on the contrary, it helps uncover new opportunities and possibilities for development and transformation (Tversky and Suwa 2009). Akdag (2018) states that our perception is not absolute and that hybrid formations are created by overlapping images perceived through our retina and stored in long-term memory. The ambiguity of freehand drawing alters these hybrid structures, resulting in simultaneous and vivid images due to a multiplication effect (Akdag 2018).

Goldschmidt (2014) also emphasizes that the deconstruction and ambiguity of freehand drawing are important in the design process because they allow for different interpretations and the emergence of new images. Purcell and Gero (1998) add that these interpretations give designers unintentional access to other domains of their knowledge that are relevant to design but may not be part of their conscious thinking process.

Other particularities include the possibility of focusing on specific aspects of the design without losing the sense of the whole or the migration between public or private registers, thus opening the door to unexpected discoveries. Additionally, due to the highly expressive capacity of freehand drawing, designers can exaggerate, emphasize, or distort elements of the design (Tversky and Suwa 2009).

Goldschmidt (2017) states that, especially in early or conceptual stages, the chosen form of representation should allow the design process to be fluid and uninterrupted. The author lists five key factors that should be considered to ensure the flow of thought. The first is the speed of image production, an essential aspect to maintain the speed of the designer's thinking process. The second is that the rules for producing representations should be minimal and reduced to the essentials, requiring the designer to use the minimum number of cognitive resources so they can focus on searching for ideas. Third, the representation should be tolerant of inaccuracy and incompleteness to avoid premature commitments to a particular idea. Fourth, the representations should be transformative and reversible, considering that the design process is not linear, and the designer may need to go back and make substantial changes. Finally, the representations should have flexible stop rules, allowing the designer to stop at any time without losing the information already produced.

The factors that ensure designers can efficiently generate and redefine their design ideas without interruptions and constraints are all made possible by freehand drawing. Therefore, it is perhaps the most complete instrument to support the design process

(Goldschmidt 2017). For these reasons, Goldschmidt and Porter (2014) suggest that there are currently no substitutes with the same potential as freehand drawing when it comes to the individual process of defining design concepts, especially in the initial phases. However, Goldschmidt (2017) emphasizes that for designers to take full advantage of freehand drawing, they need to be experienced and proficient in drawing.

According to Yu and Gero (2020), freehand drawing is an efficient way to extend mental imagery—not just to record ideas, but especially to generate them. Given its ambiguous nature, semantic density, and the possibility of interacting and transforming between ideas, freehand drawing plays a crucial role in the conceptualization of design.

Tversky (2015) suggests that thinking can easily exceed the capacities of the mind and, therefore, to expand the mind, people can use anything at hand, such as simple hand or body gestures, sticks, stones, coffee cups, drawing in the sand, or scribbling on paper napkins.

Goldschmidt and Porter (2014) also support the importance of freehand drawing in the design process. They suggest that freehand drawing is the most immediate and easy external device that designers can use to amplify mental imagery, as it is the most efficient, cognitively economical, and quickest means of experimentation. However, and this is very relevant, Goldschmidt and Porter (2014) point out that the benefits of freehand drawing are reduced for designers with poor drawing skills, emphasizing that training and practice are necessary to access the potential of freehand drawing.

Nolte (2001) states that the most important aspect of freehand drawing in the design process is not the drawing itself but the surface structure. The sense of ideas is embedded in a sense-making activity that is not linked to a particular conceptual tool but to diverse ways of articulating and processing information. Thus, according to Nolte (2001), the way of using freehand drawing is more important than the instrument itself.

When searching for a design solution, the designer can redraw the same drawing several times, sometimes overlaying existing lines to refine a gesture or using multiple layers of tracing paper to create new representations, each time making gradual changes to the original drawing. After producing a drawing, designers can read their own representations to develop their ideas further. They draw, inspect, and review their own drawings, engaging in a kind of conversation with themselves (Soygenis et al. 2010).

Studies have shown that when searching for a design solution through graphical media, the use of re-representations and multiple representations is necessary (Oxman 1997, in Dorta et al. 2016). Bilda and Gero (2006) also refer, based on observational evidence from students, that re-representation is a key operation to solve a design problem.

On the other hand, as Goldschmidt (1992) notes, when studying contemporary drawings produced by artists and designers in exploratory stages of their work, single drawings are quite rare. Freehand drawings are usually produced in series, often within a short period, sometimes just minutes. These can be done in short or long sequences, encouraging the search for as long as necessary. If needed, freehand drawings can be easily discarded since the effort involved in making them is reduced, thus facilitating a fresh start when needed. Therefore, we can consider freehand drawing very economical in terms of cognitive goal-oriented activity, which explains its widespread and universally extensive use in design (Goldschmidt and Porter 2014).

2.3.2 Freehand drawing and digital tools

The use of digital tools in architectural design has become widespread both in professional practice and in architectural education. It is well known that computer-aided design has become a standard in the field of architecture, and it would be unrealistic to think that any contemporary architecture office does not use digital tools such as CAD or BIM (Leandri 2021). In fact, due to the increasing complexity of current construction projects, as well as the need for coordination between a diverse range of specialties, many regulatory entities have encouraged or even required the use of BIM (Taraszkiewicz 2021).

Considering these developments, digital tools have been widely introduced in the field of architectural education, leading to discussions about the relevance of continuing to invest in traditional forms of representation, such as freehand drawing and physical models (Garner 2012). In many cases, these traditional methods have started to disappear in various architecture schools (Taraszkiewicz 2021).

The role of both digital tools and traditional forms of representation, including freehand drawing, has been a topic of debate among architects and educators. However, as Garner (2012) points out, freehand drawing continues to play a crucial role in design, especially in the context of design teaching. In fact, if we consult the UNESCO-UIA Charter for Architectural Education (2023), conventional drawing skills are still a requirement in educational programs and should be accompanied by comprehensive training in digital tools, covering all aspects of architectural education.

On the one hand, we see that freehand drawing is important as a design tool during the design process due to its unique characteristics as a form of representation. It is because of these characteristics that Vistisen (2015), referring to the work of Goel (1995), argues for the relevance of freehand drawing as visual thinking, facilitating both lateral and vertical transformations. That is, freehand drawing facilitates both the movement of a design idea

towards deeper understanding and accuracy, as well as the movement between different design ideas.

On the other hand, particularly in the context of design critiques, freehand drawing has great advantages in the rapid exchange of design ideas and accurate communication among students or with instructors. The literature often refers to the importance of freehand drawing in the early stages of the design process, where ideas are in great instability and constant change. However, as Taraszkiewicz (2021) points out, freehand drawing is also an important complement to verbal communication and the manipulation of different forms of representation throughout the entire design process.

When considering digital media, the advantages of computer-aided procedures in the design process are significant and varied. These include easy storage and sharing, the ease of revising design representations, the ability to quickly generate several alternative solutions, and 3D visualizations (Putra et al. 2022). The use of digital tools also enables efficient coordination of complicated design actions, especially in large-scale design projects (Juzwa and Krotowski 2018). Additionally, digital tools facilitate rapid and efficient communication regarding specific technical aspects such as structural, mechanical, electrical, or diverse areas like landscape and interior design (Juzwa and Krotowski 2018). From a creative standpoint, digital tools have opened immense potential (Oxman 1997).

However, despite the advantages brought by computer-based media, there are concerns about relying solely on digital tools as a support for the design process, as well as a lack of discussion about the relationships between different instruments, their interactions, and joint possibilities.

As Taraszkiewicz (2021) argues, in many architecture schools, students continue to be taught freehand drawing while also receiving training in digital tools. There are no classes explaining the utility and role of a particular instrument in a specific phase of the design process. This lack of education often results in students being unable to apply the knowledge they have gained in freehand drawing, drafting geometry, and other subjects that require the use of both analog and digital techniques in architectural design.

The plethora of digital tools available today, coupled with the lack of proper training on how to use them, often leads architecture students to face an over-choice phenomenon. This phenomenon refers to a situation where individuals have too many options to choose from and are unable to decide which one to use for a particular situation or phase of the design process. Thus, the student, devoid of freehand drawing as a basic instrument and without knowing how to choose the most suitable digital tool, can result in chaotic trial-and-error operations that waste time and resources, often leading to dissatisfaction (Taraszkiewicz 2021).

While the introduction of digital media and virtual environments in the design studio is expected to bring a qualitative and quantitative change in the learning experience, it is not a guarantee in itself. Computer-based media alone do not seem to ensure that students will learn more effectively or that their learning experience will be improved (Olmos 2006).

As Dorta et al. (2016) mention, the widespread adoption of laptops has had a profound impact on the dynamics of the design studio. A meaningful change was the type of representations produced by students and brought to design critiques, which were mostly inflexible and difficult to manipulate. This, combined with an essentially digital medium, has made design critiques limited to verbal communication, comments, and suggestions, and essentially non-interactive.

Furthermore, Salman et al. (2014) demonstrated how the use of computer-aided design software by students had a significant impact on the educational context by altering the design process itself. The immediacy of visual feedback provided by software leads to students spending more time on each design idea than when using traditional methods. This is important because Salman et al. suggest that working predominantly with CAD software hinders design moves, especially horizontal movements.

On the other hand, students take less time to analyze the design program and spend more time focusing on detailing the proposed solution, shifting their attention away from conceptual content and towards operative movements that can become tiring and distracting (Salman et al. 2014).

Therefore, Goldschmidt (2017) argues that freehand drawing still has important attributes for the design process, but it should be used in integration with digital tools in a mixed practice. Have and Toorn (2012) also highlight the advantages of using hybrid forms of representation, combining analog and digital media to take full advantage of the strengths of each while reducing their weaknesses.

Chapter 3 Methodology and position

3.1 Presentation

One of the most important criteria for determining the scientific validity and reliability of research has to do with its methods and how these constitute a methodology. According to Yin (1984), it is precisely the explicit and clear enunciation of these methods, whether for data collection or analysis, that can guarantee the quality standards of research and make its results of inter- and transdisciplinary value.

Moreover, a well-structured and well-described methodology can be an important contribution in itself, serving as a basis for future research in similar settings (Yin 1984). If quantitative approaches already have an established place in architectural research, imported from other disciplinary fields such as engineering, the same does not seem to apply to qualitative or mixed methods approaches, in which there is still a long way to go (Li et al. 2021). One of the topics clearly deficient in terms of qualitative and mixed empirical data is architectural education, as evidenced by the literature review (see 1.4. Review).

To enhance and streamline the methodology for a research project, one valuable strategy is to draw from relevant precedents as references (Bhattacherjee 2012). Depending on the specific research goals, these precedents can be combined or adapted to tailor the methodological procedures to the subject and perspective in question. However, in cases where prior examples are limited or nonexistent, as was the situation in our research context—centered on examining educational practices within their specific context—a necessity emerges to establish a methodological framework.

This framework, similar to the development of a theoretical framework, serves as a guide in determining the research approach, design, and specific methods for data collection and analysis, including the establishment of precise criteria. For the development of this framework, we conducted a review of specialized literature, with a focus on quantitative and mixed methods field research within educational contexts. The outcomes of this review were already presented in two articles (Sousa Santos et al. 2021a; Sousa Santos et al. 2021b) during a conference on qualitative methods.

This chapter is structured as follows: first, it presents the findings from a narrative literature review, focusing on qualitative research in education. It begins by examining research approaches, their types, and selection criteria, concluding with specific characteristics of qualitative methodologies. The discussion then shifts to research design, covering various strategies in qualitative research along with their features and selection

criteria. Emphasis is placed on an in-depth exploration of the case study strategy due to its significance in educational research. The first part concludes with a discussion on research methods, spanning data collection, recording procedures, and analysis to interpretation.

In the second section, leveraging insights from the literature review, we outline the methodology for this research. Beginning with a broad delineation, we define a qualitative approach and adopt a multiple embedded case study design. We then delve into the specifics of data collection and analysis methods, covering initial definitions and subsequent modifications made during our work. Critical considerations accompany these descriptions, shedding light on the rationale behind our decisions.

In the third part of this chapter, we delve into the concept of a theoretical position. This refers to the underlying philosophy that guides research, shaping both the chosen methodology and the analysis of data. We explore how this theoretical position is influenced by factors such as the researcher's worldview, the nature of the research problem, and the selected methodology. We then discuss two specific theoretical positions in this research, along with their particularities.

3.2 Review

3.2.1 Research approach

The research approach is the term used to refer to the overall plan that guides research. There are three types of approaches: quantitative (QUAN), qualitative (QUAL), and mixed methods (MM). A first distinction between QUAN and QUAL approaches can be made based on the type of data they use. While QUAN approaches collect, record, analyze, and interpret numerically measurable data, QUAL approaches depend on "non-numerical evidence, whether verbal (oral or written), experiential (film or notes), or related to artifacts (objects, buildings, urban spaces)" (Groat and Wang 2013, 69).

However, the differences between QUAN and QUAL approaches are more substantial. John Creswell (1994) distinguishes the two based on their ontological, epistemological, and methodological dimensions. Ontologically, QUAN approaches assume reality to be unique and objective, while QUAL approaches understand reality as being multiple and subjective. Epistemologically, QUAN approaches do not consider the researcher's interaction with the object of study, unlike QUAL approaches. Finally, methodologically, QUAN approaches are usually based on a logical-deductive method, while QUAL approaches follow a logical-inductive method.

Despite this dichotomy, Creswell (2014) refers to the idea that QUAN and QUAL approaches should not be understood as rigid categories, as they are usually used in the same study,

regardless of its type. Studies tend to be "more quantitative" or "more qualitative." MM approaches, on the other hand, are characterized by combining the characteristics of QUAN and QUAL approaches. Although some authors understand MM approaches solely based on methodological dimensions, such as data collection, recording, analysis, and interpretation methods, they are more than that (Tashakkori and Creswell 2007a). In addition to combining methods, different ontological, epistemological, and methodological conceptions are also integrated to take advantage of the strengths, and minimize the limitations of, each approach.

research approach	ontology	epistemology	methodology
QUAN	reality is objective and singular	knowledge is independent of the researcher	deductive methods
QUAL	reality is subjective and multiple	researcher's and participants' perspectives are crucial	inductive methods
MM	reality can be objective or subjective	knowledge may or may not be linked to the researcher	both

Table 10. Research approaches—adapted from Hatch (2002, 13)

Creswell (in Borrego, Douglas, and Amelink, 2009) outlines three criteria for defining the type of approach: (i) the nature of the research problem; (ii) the researcher's background and experience; (iii) the target audience. According to John Dewey (in Abbagnano 1984), a problem is a statement of a situation that lacks a single meaning or includes alternatives and serves as the starting point for any inquiry. It differs from the issue, which is defined as an "organized or systematic collection of problems" (1984, 796). Creswell (2014), in turn, defines the research problem as a question or concern to be addressed. The research problem may arise from a gap in the literature, conflicts between results identified in the literature, or simply topics that have been inadequately addressed.

As the second criterion, Creswell (2014) mentions the importance of considering the researcher's field of expertise and personal experience. For a researcher with knowledge in technical-scientific writing, statistics, QUAN data processing software, and who frequently relies on evidence-based QUAN literature, it would be more convenient to choose a QUAN approach (2014). In the case of researchers used to writing in a literary style, with experience in conducting interviews or field observation processes, they are better suited to follow a QUAL approach. Researchers who decide to use an MM approach should be familiar with aspects of both QUAN and QUAL approaches and have the time and resources available, as it involves complex data collection and analysis processes. In the case of investigations

conducted by students, Creswell (2014) recommends that they also consider the approaches typically followed by their academic supervisors.

The same question arises regarding the third criterion, the intended audience for the research. As Creswell (2014) points out, researchers write for a specific audience, such as editors and readers of scientific journals, faculty review boards and committees, conference participants, or fellow researchers. Therefore, the preferences of this audience for QUAN, QUAL, or MM approaches should be considered.

But what are the particularities of QUAL approaches? According to Salkind (2010), QUAL approaches are a type of study historically linked to anthropology, sociology, and humanities, with the particularity of dealing mostly with non-numerical forms of data or empirical evidence. As already mentioned, from an ontological perspective, QUAL approaches conceive reality as subjective and multiple, meaning that the nature of reality is not independent of the individual and collective subject—it is actually generated through social interaction, making it circumstantial and therefore mutable (Salkind 2010).

From an epistemological perspective, QUAL approaches have an interpretative character (Hatch 2002), as it is up to the researcher to interpret the meaning of the collected data. Therefore, the researcher plays a fundamental role in a QUAL approach, either as a passive observer—since the main data is directly collected and filtered by the researcher, "contaminating" the process with their values and identity (Salkind 2010)—or as a participatory observer—actively interfering in the object of study.

Another aspect of QUAL approaches, as Yin (2011) points out, is the alteration of the concept of generality, characteristic of QUAN approaches, by transferability. Through a detailed and thorough description of the specific context, the researcher allows the reader to make connections between the study and their own situation. On the other hand, given the subjective-interpretative nature of this type of approach, exhaustive documentation of data collection, recording, analysis, and interpretation procedures should also be elaborated to ensure the reliability of the research.

From a methodological perspective, Creswell describes QUAL approaches as multifaceted (being both inductive and deductive), simultaneous (not following a linear sequence in the processes of data collection, recording, analysis, and interpretation), and interactive (due to the comprehensive, flexible, and emergent nature of the study procedures). It is precisely the interactive dimension of the QUAL approach that many authors underline as an important characteristic of this type of study. Unlike the usually fixed and predetermined nature of QUAN approaches, the nature of QUAL approaches is characterized by the openness, flexibility, and emergence of its procedures in response to the realities of the environment under study (Hatch 2002).

Therefore, it is common for research questions to be redefined during QUAL research, for methods of data collection, recording, analysis, and interpretation to be altered, and even for the sources of evidence to be replaced as knowledge of the problem develops and deepens. As Hatch (2002) states, the QUAL researcher is not putting together the pieces of a puzzle of which they already know the figure; they are building a figure that takes shape as the pieces are collected and examined.

3.2.2 Research design

David de Vaus (2001) defines the research design as the logical structure of a study within a particular research approach, with the main objective of ensuring that the evidence collected allows researchers to answer research questions or test theories in the least ambiguous way possible. Within the scope of the research design, there are also three major groups defined by the type of data used: QUAN, QUAL, and MM.

As previously mentioned, QUAL studies have the particularity that the research design can be emergent, meaning that it can arise in the development of the work itself—particularly in educational settings (Hatch 2002). As Hatch (2002) notes, since the objective is to enter a social phenomenon embedded in a particular social context, it is impossible to construct an *a priori* design that considers the discoveries that will emerge from the contact between the researcher and the observed reality.

However, Yin (1984) argues that QUAL research should start with an established, albeit provisional, design that functions as a coordinate for the development of the work. Due to this provisional nature, and in continuity with Yin's proposal, Hatch (2002) recommends that the research design for QUAL research be conceived with a flexible structure. This way, the researcher can embark on the research with an "action plan" (Hatch 2002, 38) that coordinates the development of the study but is also sensitive and permeable to the transformations that real circumstances may suggest or dictate.

Associated with the design is the research strategy, which pertains to the overarching strategy that guides the procedures for data collection, recording, analysis, and interpretation. In the case of QUAL designs, narrative, survey, experimental, archival, historical, ethnographic, or case study research strategies are followed (Creswell 2014). Yin (1984) outlines three criteria for selecting the type of strategy: (i) the type of research question or problem; (ii) the degree of control the researcher has over behavioral events; (iii) the degree of focus on contemporary events and the need (or lack thereof) to consider the context. The correspondence between the criteria and types of research strategy is illustrated in Table 11.

research strategy	type of research question	requires control of behavioral events?	considers contemporary events?
experimental	how, why	yes	yes
survey	who, what, where how many, how much	no	yes
archival	who, what, where how many, how much	no	yes/no
historical	how, why	no	no
case study	how, why	no	yes

Table 11. Research strategies—adapted from Yin (1984, 5)

Since we are focusing on the case study as our research strategy, what key information should we explore? The case study is defined by Yin (1984) as empirical research that addresses a contemporary phenomenon in its real context, especially when the boundaries between the phenomenon and the context are not clear. As a research strategy, the case study is often adopted in educational research (Merriam 1998; Stake 1995; Yin 1984). A case study involves the research of a well-defined phenomenon in a real-life context (Yin 1981; Gerring 2004). One of the fundamental dimensions of a case study is systematic comparison, where researchers seek to identify similarities and differences between cases (Dumez 2016).

The case study has the particularity of being able to deal with a wide variety of sources of evidence—such as documents, artifacts, interviews, and observations—and even with different types of data. Although a large number of case studies are framed in QUAN approaches, they are a type of strategy suitable for the association of QUAL data and, therefore, widely used in MM approaches.

In this regard, educational research is often carried out using a case study strategy, as mentioned by Yin (1984), Sharan Merriam (1998), and Robert Stake (1995). Considering the criteria previously defined by Yin (1984), case study strategies are suitable when addressing "how" or "why" questions and have an exploratory nature. On the other hand, case study strategies are particularly appropriate when it is not possible to manipulate the behaviors to be analyzed, unlike experiments where behaviors can be manipulated by the investigator with precision and systematic control (Yin 1984). Finally, case study strategies are indicated when it is important to consider contemporary events within a specific context.

Yin (1984) recommends that when defining a research project using a case study strategy, three main aspects should be considered: (i) the number of cases to be studied; (ii) the definition of units of analysis; and (iii) the logical connection between the collected data and

the research propositions or the research problem. Regarding the first aspect, in the context of educational research, it is common to define each institution or school as an autonomous case study. Thus, if a study focuses on a single institution, it is a single-case study strategy, and if it involves multiple institutions, it is a multiple-case study strategy.

Regarding the second aspect, the selection of units of analysis is linked to the definition of the research questions themselves. If the research questions do not direct toward a specific unit of analysis, then the questions may be too vague or numerous. However, even when the units of analysis are established, it is important not to consider them as final—there may be a need to revise them based on any discoveries during data collection (Yin 1984).

Regarding the third aspect, Yin (1984) emphasizes the importance of considering how the logical connection between the data and the research propositions or the research problem will be established. In other words, what rule underpins the procedures of analysis and interpretation? This aspect should not only be considered but should also be clearly explained in the research's methodological procedures—this is a condition for the validity of the study's results.

3.2.3 Research methods

After selecting the research approach and design, the next step is determining the most appropriate research methods to address the formulated problem, meaning the selection of tools or techniques for data collection, recording, analysis, and interpretation (Creswell 2014). Salkind (2010) and Yin (2011) mention the primary methods for qualitative evidence collection as interviews and conversations (individual or group), observation (participatory or non-participatory), and the collection of documentation and artifacts (whether pre-existing or generated as part of the study process), as indicated in Table 12.

The methods of analysis, in turn, must be tailored to the nature of the collected evidence. In a qualitative context, as noted by Salkind (2010) and Creswell (2014), methods such as thematic analysis (where the researcher analyzes the texts produced from interviews, field notes, and documents, then applies codes and develops themes), discourse analysis (where the researcher studies the structure, rhythm, and patterns of discourse), or narrative analysis (where the researcher explores how life stories are constructed) are frequently used (Salkind 2010). Some researchers use specialized software for this type of study, which can be very helpful in organizing and handling large quantities and diverse types of evidence.

methods for data collection	type of data	examples of data
interview and conversation	verbal and body language	an individual's explanation of a particular behavior or action; a recollection
participative or non-participative observation	behaviors, social interactions, actions, physical environment	the level of coordination between two individuals; the nature of this coordination; spatial characteristics
collection of documents	personal documents, graphical material, archival records, physical artifacts	titles, texts, dates, and chronologies; entries in an archival record

Table 12. Data collection methods in QUAN research—adapted from Yin (2011, 131)

From Yin (1984), Manion (1980), and Creswell (1994, 2014), three main aspects have been synthesized to consider when defining data collection and recording methods in qualitative case studies: (i) the use of multiple methods, sources of evidence, and possibly types of data; (ii) the explicit linkage of evidence with the study; and (iii) the development of a database.

Regarding the first aspect, all three authors emphasize the importance of qualitative case studies being based on multiple methods (utilizing various methods for data collection, recording, analysis, and interpretation), using multiple sources (employing diverse sources of evidence that converge regarding the same set of facts), and, as Yin (1984) especially advocates, employing different types of data (complementing QUAL data with QUAN data, even in a QUAL research).

Concerning the second aspect, Yin (1984) underscores the significance of explicitly stating the relationships between research questions, the sources of evidence to be used, the types of data to be collected, and their purposes. Finally, concerning the third aspect, all three authors mention the operational benefits of creating a formal assembly of different pieces of evidence in the form of a database—not only during the data collection and recording phase but also during the analysis and interpretation phase.

The analysis and interpretation of data, as Merriam (2009, 176) notes, is the complex process of making sense of the collected data through procedures of consolidation, reduction, and reading. Hatch (2002, 148) also defines data analysis and interpretation as a systematic search for meaning.

Merriam (1998), based on Bogdan and Biklen (2007), provides a set of recommendations for researchers during the process of data analysis and interpretation in qualitative studies. As the first recommendation, Merriam (1998) states that, contrary to what a rigid idea of sequentiality may suggest, the four stages of data collection, recording, analysis, and interpretation should take place simultaneously, whether "in" or "out" of the field. This way, the researcher has the opportunity to adjust or modify data collection and recording

procedures—or even research questions—based on the results of previous sessions. To do this, it is necessary to analyze the data continuously, even if it is done in a rudimentary way.

On the other hand, a portion of the literature review should also occur during and after fieldwork (Merriam 1998). To reinforce this idea, when Creswell (2014, 246) outlines what he considers the general steps of data analysis, he states, "This outline suggests a linear and hierarchical approach built from the bottom up, but I see it as interactive: the various phases are interrelated and do not necessarily follow in this order."

Merriam (1998) suggests that ideas, analysis categories, results, and others be tested with the participants, meaning they should be presented to the subjects of the study—especially in the case of interviewees—as elements of the ongoing study. This recommendation is particularly relevant in an educational context, considering the input that teachers and researchers can bring to the study.

3.3 Definition

3.3.1 How was the methodology defined?

As previously discussed, the first aspect to be defined is the selection of the research approach. Based on the criteria presented by Borrego et al. (2009), the selection of the approach depends on (i) the nature of the research questions, (ii) the researcher's background and experience, and (iii) the target audience. The last two criteria have limited influence on defining the approach, as the field of architecture itself does not inherently prescribe a direction for research. Typically, architectural research draws from the assumptions and strategies of the social sciences, as noted by Creswell (2014, 1994) and Stake (1995). However, it is the specific research problem at hand that ultimately shapes the approach to be taken, as underscored by Yin (1984).

In our case, the nature of the research questions, particularly the second and third ones, which are characterized by their explanatory and exploratory character, and framed as "how" and "why" questions, align with QUAL approaches (Yin 1984). Consequently, our research will be primarily QUAL, with certain QUAN data as supplementary.

The next step involves defining the research design, which serves as the logical structure of the study, with the primary objective of ensuring that the collected evidence allows for clear answers to the research questions (de Vaus 2001). In QUAL research, the research design often comprises strategies such as narrative, survey, experimental, archival, historical, ethnographic, or case study (Creswell 2014).

According to Yin (1984), the selection of the research strategy should take into account three primary conditions: (i) the type of research question or problem, (ii) the extent of control the

researcher has over behavioral events, and (iii) the focus on contemporary events within a specific context.

Concerning the first condition, as mentioned earlier, this study revolves around research questions with an explanatory and exploratory nature (how and why freehand drawing is used in architectural design teaching). In these cases, research strategies like case studies, experiments, or historical analyses are recommended (Yin 1984). Regarding the second condition, our aim is to investigate a phenomenon that cannot be subject to behavioral manipulation (architectural design teaching). Therefore, as Yin (1984) suggests, case study and historical research strategies are the most appropriate choices. Lastly, concerning the third condition, the necessity to focus on contemporary events within a specific context (three architecture schools), emphasizes the suitability of a case study strategy.

Case studies are empirical studies that explore current phenomena in real-world situations, especially when the distinctions between the phenomenon and its context are unclear. As a research method, case studies are commonly applied in educational research, as highlighted by Merriam (1998) and Stake (1995).

As highlighted in the thesis introduction, our research revolves around three distinct case studies: the Faculty of Architecture of the University of Porto (FAUP), the *Scuola di Architettura Urbanistica e Ingegneria delle Costruzioni of the Politecnico di Milano* (POLIMI), and the Massachusetts Institute of Technology School of Architecture and Planning (MIT).

Initiating our exploration with the FAUP, chosen as the primary host institution, the rationale for selecting the other two cases evolved from the convergence of three key criteria: (i) recognition of the institutions' merit, both on a national scale, where they are seen as benchmarks in architectural education, and internationally; (ii) making a deliberate effort to showcase diverse approaches to architectural education, considering their roots in technical or artistic foundations. This led to initial visits and sometimes reconsideration of cases if they did not fit well or were too similar to the first one chosen; (iii) lastly, logistics played a crucial role. After selecting a potential case, ensuring a supportive host for the research became essential. Particularly in the case of the U.S., success depended on securing additional funding to sustain the mobility period.

Referring again to Yin (1984), the definition of a research design based on a case study should consider three key aspects: (i) the number of cases to be examined, (ii) the selection of units of analysis, and (iii) the establishment of a logical link between the gathered data and the research problem. Regarding the first aspect, as we have seen, this research intends to investigate three educational institutions. Following the framework outlined by Yin (1984), it is common for each institution-school to be treated as an independent case. Therefore, in contrast to single-case studies, this research will adopt a multiple-case study design.

Concerning the second aspect, the objective of this research is to focus on a specific phenomenon, namely, the teaching of architectural design, within each case institution. The aim is not to analyze the cases as a whole, from a holistic perspective, but to focus on a study subject composed of a set of embedded units of analysis. As a result, the research will employ a multiple-case study design, encompassing three units of analysis: the context (UA_CTX), the design process (UA_PRO), and design critiques (UA_CRI).

Regarding the third aspect, the aim is to establish a connection between the collected data and the research problem using a logical deductive-inductive method, beginning with an overarching picture (general) before delving into the specific study object (particular).

3.3.2 How was data collected?

Yin (1984), Manion (1980), and Creswell (1994, 2014) advocate for a comprehensive approach in QUAL studies of this nature, emphasizing the need for a combination of multi-methods, multi-sources, and multi-types of data. In line with this principle, and to guide the data collection procedures, a synthesis table has been prepared, detailing the data sources, collection methods employed, types of data gathered, and the corresponding units of analysis.

case	data sources	research methods	data types	units
cs_a	curricular plans	documents collection	qual + quan	ua_ctx ua_pro ua_cri
	design classes	observation	qual + quan	
	instructors, students	in-person interview	qual	
	classes programs	documents collection	qual + quan	
cs_b	curricular plans	documents collection	qual + quan	ua_ctx ua_pro ua_cri
	design classes	observation	qual + quan	
	instructors, students	in-person interview	qual	
	classes programs	documents collection	qual + quan	
cs_c	curricular plans	documents collection	qual + quan	ua_ctx ua_pro ua_cri
	design classes	observation	qual + quan	
	instructors, students	in-person interview	qual	
	classes programs	documents collection	qual + quan	

Table13. Data collection methods

Data collection in all three case studies primarily involved fieldwork sessions where naturalistic and participatory observation methods were used to quantify and qualify the use of representation during the design studios. The choice between these methods depended on the specific case and the availability of instructors. Typically, the candidate aimed to minimize interference with the normal flow of classes, adopting a non-intrusive approach. Nonetheless, there were occasions when instructors invited the candidate to become actively involved in the classes, providing feedback on students' work, serving as a

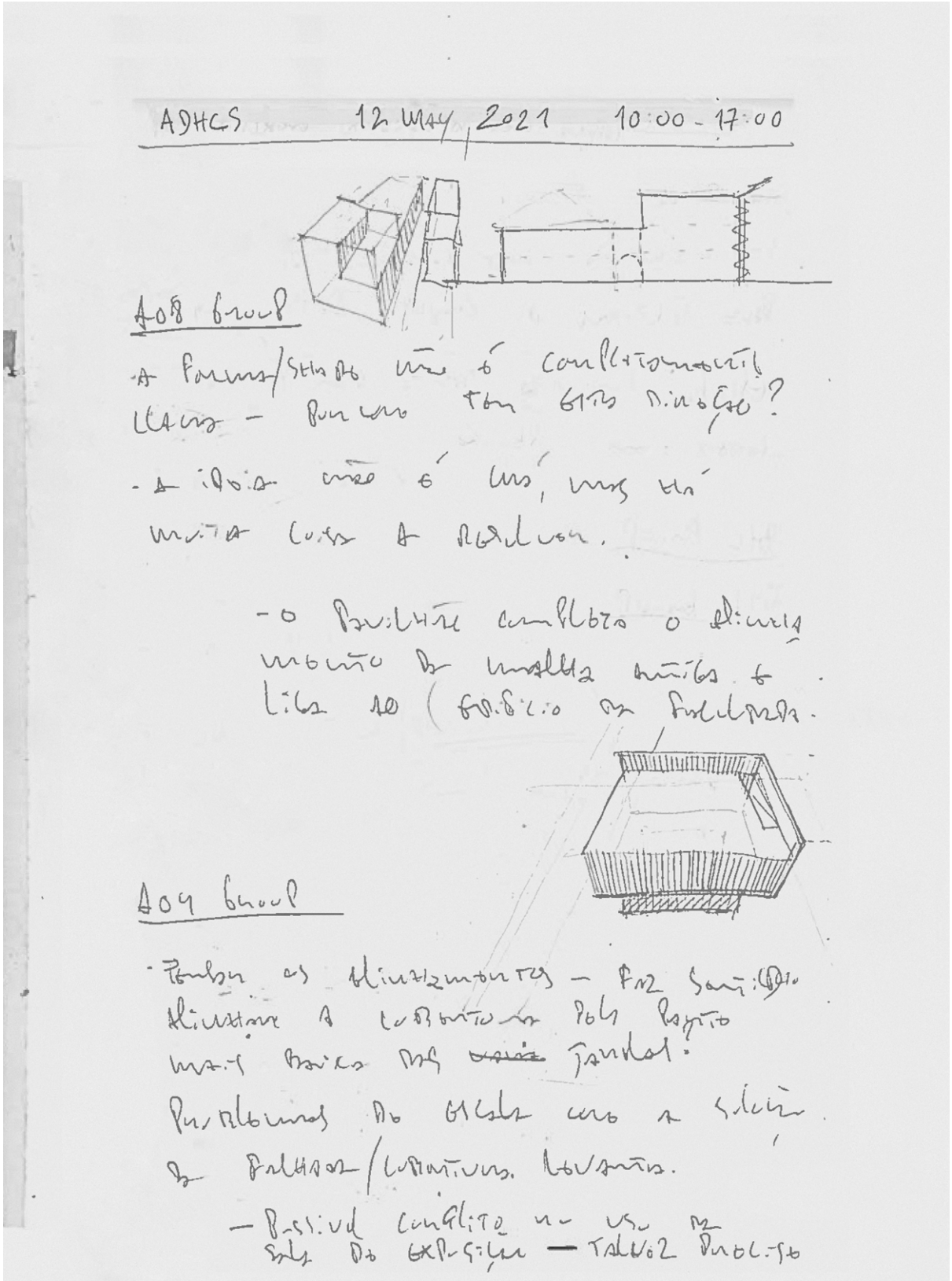


Figure 1. Notebook used in fieldwork sessions, Mantua, 2021

jury during final presentations, and even participating as a teaching assistant for short periods.

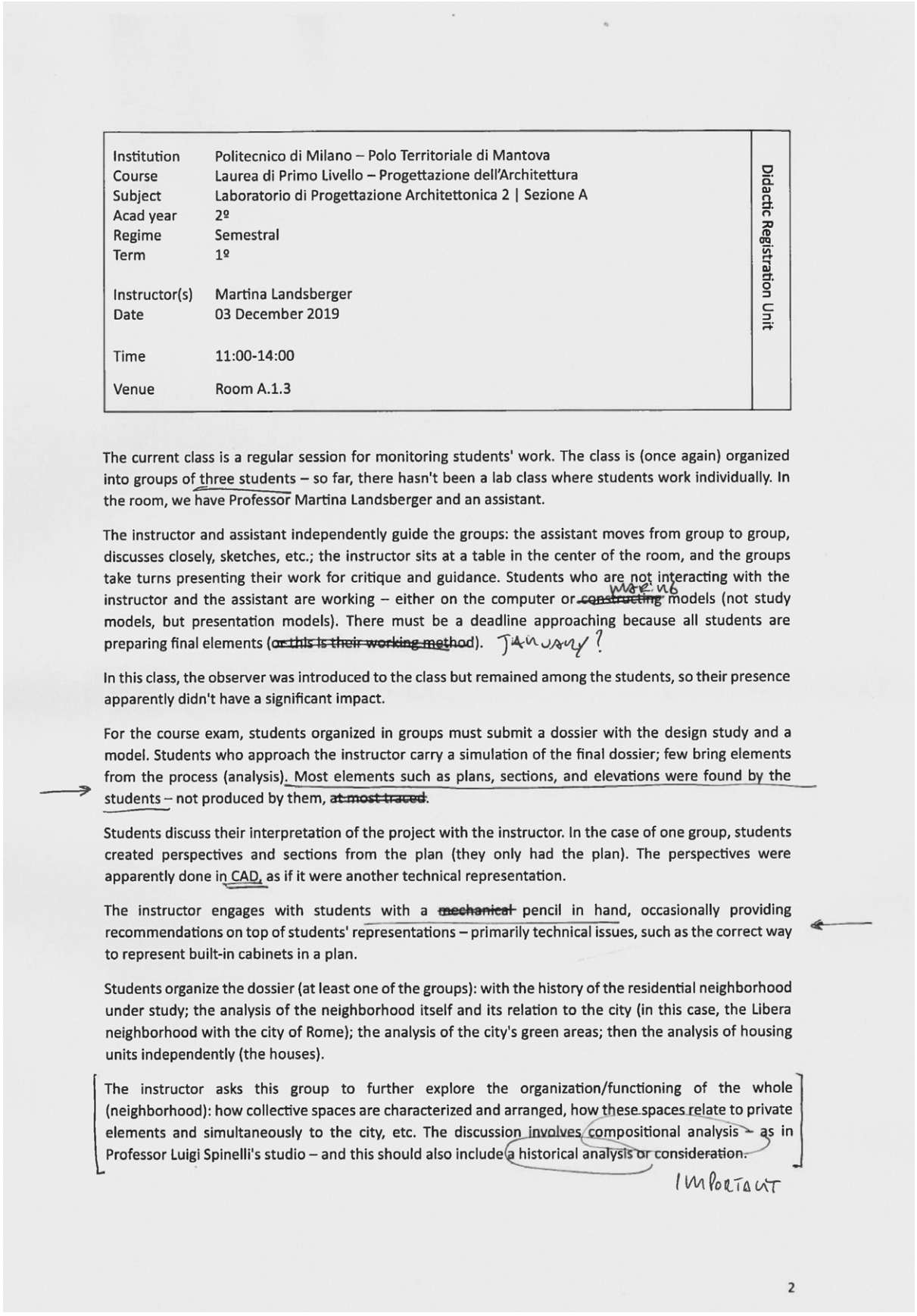
The data collection process primarily consisted of taking raw field notes (Figure 1) during class observations. Additionally, curricular documents and reports were collected to gain insights into course objectives, schedules, and recommended reading materials. Field notes were later transcribed into a digital format referred to as Didactic Registration Units (DRU). This transcription process served as a preliminary stage for selecting and summarizing the collected materials. It also helped evaluate the effectiveness of data collection procedures, which, in turn, informed future data collection sessions (Figure 2).

Whenever possible, photographic records were taken with a focus on minimizing disruption to regular class activities. These photographs served a dual purpose: documenting the teaching environment and capturing unique aspects of materials produced by students and instructors. Although photographic records had limited relevance during data analysis, they were important in visually communicating the research findings.

The primary emphasis during fieldwork was on the design studios. The objective was to observe students from various academic years to gain insights into students' backgrounds and education, instructor expectations, and curriculum in the three schools. The types of classes observed included design critiques, pin-up sessions, mid-term reviews, final presentations, and theoretical classes. In addition to in-person fieldwork, remote classes were also attended, particularly during the second wave of the Covid-19 pandemic between November and March 2021.

As noticed during data collection, systematic direct observation helps mitigate the initial awkwardness of the researcher's presence for both instructors and students. In the initial observed classes, the candidate's presence often influenced subject behavior due to the novelty of the situation. Systematic observation also allows for the identification of exceptional situations that may occur during classes. For instance, it was noted in all three schools that instructors tended to showcase the best student works as exemplary cases, which could potentially introduce bias into the research findings. Extensive class observations, covering different teaching moments, are therefore relevant for a comprehensive understanding of events and behaviors.

Furthermore, this approach enabled the contributions of research subjects themselves, namely instructors and students. Spontaneous conversations that occur during fieldwork are invaluable, serving as a form of open interviews, as highlighted by Yin (1984). These conversations offer direct input, including literature recommendations, while also providing opportunities to get feedback on research results, interpretations, and methodological procedures being employed.



Institution	Politecnico di Milano – Polo Territoriale di Mantova	Didactic Registration Unit
Course	Laurea di Primo Livello – Progettazione dell'Architettura	
Subject	Laboratorio di Progettazione Architettonica 2 | Sezione A	
Acad year	2º	
Regime	Semestral	
Term	1º	
Instructor(s)	Martina Landsberger	
Date	03 December 2019	
Time	11:00-14:00	
Venue	Room A.1.3	

The current class is a regular session for monitoring students' work. The class is (once again) organized into groups of three students – so far, there hasn't been a lab class where students work individually. In the room, we have Professor Martina Landsberger and an assistant.

The instructor and assistant independently guide the groups: the assistant moves from group to group, discusses closely, sketches, etc.; the instructor sits at a table in the center of the room, and the groups take turns presenting their work for critique and guidance. Students who are not interacting with the instructor and the assistant are working – either on the computer or ~~constructing~~ working models (not study models, but presentation models). There must be a deadline approaching because all students are preparing final elements (~~or this is their working method~~). January?

In this class, the observer was introduced to the class but remained among the students, so their presence apparently didn't have a significant impact.

For the course exam, students organized in groups must submit a dossier with the design study and a model. Students who approach the instructor carry a simulation of the final dossier; few bring elements from the process (analysis). Most elements such as plans, sections, and elevations were found by the students – not produced by them, ~~at most traced~~.

Students discuss their interpretation of the project with the instructor. In the case of one group, students created perspectives and sections from the plan (they only had the plan). The perspectives were apparently done in CAD, as if it were another technical representation.

The instructor engages with students with a ~~mechanical~~ pencil in hand, occasionally providing recommendations on top of students' representations – primarily technical issues, such as the correct way to represent built-in cabinets in a plan.

Students organize the dossier (at least one of the groups): with the history of the residential neighborhood under study; the analysis of the neighborhood itself and its relation to the city (in this case, the Libera neighborhood with the city of Rome); the analysis of the city's green areas; then the analysis of housing units independently (the houses).

The instructor asks this group to further explore the organization/functioning of the whole (neighborhood): how collective spaces are characterized and arranged, how these spaces relate to private elements and simultaneously to the city, etc. The discussion involves compositional analysis – as in Professor Luigi Spinelli's studio – and this should also include a historical analysis or consideration.

IMPORTANT

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Figure 2. Example of a Didactic Registration Unit (DRU), Porto, 2022

3.3.3 How was data analyzed?

As Merriam (2009) argues, data analysis and interpretation involve an intricate process of extracting meaning by consolidating, reducing, and examining the collected data. In our study, we employed thematic analysis, a common approach in QUAL research, to analyze texts derived from field notes and interviews, applying codes and developing themes (Hatch 2022).

Our primary data collection method involved direct observation, conversations, and non-structured interviews. As mentioned, data were initially recorded in raw field notes on-site and subsequently transcribed into a digital format for Didactic Registration Units (DRU). Atlas.ti software facilitated the analysis of each DRU (Figure 3).

The coding process initiated with the three designated units of analysis, progressively delving into a two-tiered structure. For the first unit of analysis, context (UA_CTX), we scrutinized facets related to the organization of design studios. This encompassed considerations such as the count of instructors and students, curriculum type, specific exercises, the nature of these exercises, and overall observations gathered from the candidate, instructors, and observed students (Table 14).

class	setting	brief	observations
class_institution	sett_inst_name	brief_program	obs_general
class_doc_type	sett_inst_num	brief_detailed_program	obs_instructors
class_participant	sett_assistants_num	brief_nature	obs_students
class_program	sett_guests_num	brief_context	
class_course	sett_guests_role	brief_modality	
class_acad_year		brief_group_num	
class_system		brief_general_plan	
class_type		brief_restrictions	
class_regime		brief_specifications	
		brief_deliver	
		brief_class_work	

Table 14. Codes for the first unit of analysis Context (UA_CTX)

Turning to the second unit of analysis, the design process (UA_PRO), we examined critical aspects including the equilibrium between digital and analog representations, the nature of representations employed, and the inherent characteristics of these representations. In addition to freehand drawing, our analysis encompassed the inclusion of physical models, a prevalent representation type across all three schools. We also delved into general challenges faced by students, with a particular focus on difficulties associated with representation (Table 15).

Figure 3. Screenshots of Atlas.ti interface while coding a DRU, Porto, 2022

models	representation	fhd	difficulties
mdl_production	rep_balance	fhd_spt-demanded	diff_general
mdl_materials	rep_types	fhd_presence	diff_representation
mdl_style	rep_most_types	fhd_what	
mdl_character	rep_support	fhd_how	
mdl_scales	rep_character	fhd_where	
	rep_style		
	rep_scales		
	rep_construction		

Table15. Codes for the second unit of analysis Design Process (ua_pro).

In relation to the third unit of analysis, design critiques (UA_CRI), our approach commenced by examining the diverse modalities of critiques, along with the comments, suggestions, and actions of instructors directed towards students. Subsequently, we explored the various mediums employed in the critique process, differentiating between those utilized by instructors and students. Further investigation centered on the utilization of freehand drawing by both parties, taking into consideration aspects such as frequency, mode, type, and supporting materials (Table 16)

critiques	modes_interaction	fhd_instructors	fhd_students
cri_setting	mod_medium	fhd_inst_frequency	fhd_stud_frequency
cri_class_review	mod_intructors	fhd_inst_types	fhd_stud_spt-demanded
cri_dynamics	mod_students	fhd_inst_what	fhd_stud_types
cri_comentaries		fhd_inst_how	fhd_stud_what
cri_suggestions		fhd_inst_where	fhd_stud_how
cri_actions			fhd_stud_where

Table16. Codes for the second unit of analysis Design Critiques (UA_CRI).

In accordance with thematic analysis principles, codes emerged organically during the analysis, influenced by specific results. References from Oh et al. (2013) and Milovanovic (2019) played a significant role in code definition. The candidate performed dual coding using Atlas.ti. The initial coding of all DRUs allowed code definition and testing, with subsequent adjustments made during the second coding to reduce ambiguity and redundancy. Double coding, as recommended by Milovanovic (2019), ensures the reliability of analysis results.

id			ua_context								
			setting					brief			
id	date	year	inst_num	assistants_num	guests_num	guests_role	brief	brief_program	brief_detailed	brief_nature
1	04/abr	2022	1	1	3	lecturer	y	practical-design research	n	both
2	06/abr	2022	1	n	n		y	a robotic prototype	n	sy
3	06/mai	2022	2	1	3	reviewer	y	equipment (fragile territory)	n	both
4	07/abr	2022	1	1	n		y	equipment (historical building)	n	both
5	07/abr	2022	2	n	n		y	equipment (fragile territory)	n	both
6	08/abr	2022	1	1	1	lecturer	y	equipment (historical building)	n	both
7	08/abr	2022	2	n	n		y	equipment (fragile territory)	n	both
8	09/mai	2022	1	1	3	reviewer	y	equipment (historical building)	n	both
9	11/abr	2022	2	1	n		y	practical-design research	n	both
10	11/abr	2022	1	2	n		y	lamp, furniture	n	sy
11	13/abr	2022	1	n	n		y	a robotic prototype	n	sy
12	15/mar	2022	1	1	3	reviewer	y	free (thematic)	n	both
13	16/mar	2022	1	1	3	reviewer	y	an object (sculpture or furniture)	n	sy
14	16/mar	2022	1	2	n		y	lamp, furniture	n	sy
15	16/mai	2022	1	1	4	reviewer	y	free (thematic)	n	both
16	25/abr	2022	1	1			y	an exposition	n	sy
17	28/mar	2022	1	2	n		y	series of design object	n	sy
18	28/abr	2022	1	1	1	lecturer	y	equipment (historical building)	n	both
19	30/mar	2022	1	2	3	lecturer, reviewer	y	series of design object	n	sy
20	31/mar	2022	1	2	n		y	analysing and modulate Alvar Aalto	n	an

Figure 4. Segment of the Excel synthesis table showing the first unit of analysis (UA_CTX), Porto, 2022

Each coded DRU was exported to Microsoft Excel for further analysis. When exported to Excel, only the segment ID and associated codes were exported (Figure 4). The identifier allows us, if necessary, to find the corresponding verbalization in Atlas.ti, and therefore, the two software tools were initially used simultaneously. A comprehensive synthesis was organized containing all the data, allowing a general perspective on the data, then segmented into pivot tables for the analysis of each of the components. The table with detailed data can be consulted in the appendices (see Appendix 2).

During our research, data analysis proved to be a complex and time-consuming activity, primarily due to the absence of prior references. Again, due to the lack of former references in this domain, we had to undergo numerous trial-and-error tests to devise effective data management and manipulation strategies. This process spanned the entire duration of our study.

Throughout this research, alongside the core analysis, a series of side studies, referred to as Complementary Readings, were conducted. These studies had a dual purpose. On one hand, they aimed to delve into aspects that were not addressed in the primary analysis, such as how freehand drawing is taught outside of design studios (Sousa Santos et al., 2021a), or the implications of online teaching in design teaching during the pandemic (Sousa Santos et al., 2021b). Simultaneously, these Complementary Readings served to test data analysis methods, which, in turn, informed our main research.

We presented the findings from these partial studies at conferences to gather feedback from our peers. This process shed light on both strengths and weaknesses, providing valuable insights for the core analysis. These conferences also exposed us to other ongoing research that, while not directly related, offered relevant methodological possibilities. For instance, our initial attempts at data analysis did not include specialized software, resulting in a time-consuming and intricate process due to the diversity and volume of data.

As the work progressed and the complexity of collected data increased, it became apparent that conducting rigorous and systematic data analysis was impractical without a specialized tool. Such a tool needed to efficiently code the Didactic Registration Unit (DRU) according to a theme and sub-theme structure, facilitate the swift and effective storage and manipulation of data, and streamline the cross-referencing and analysis of both QUAL and QUAN data. It was during a conference that the use of Atlas.ti, complemented with Excel, was recommended to streamline the analysis procedures, ensuring the rigor and validity of our results.

3.4 Position

Research positions, also referred to as philosophical worldviews (Creswell, 2014), research paradigms (Hatch, 2002), or assumptions (Manion, Cohen, and Morrison, 1980), correspond to "philosophical stances that provide the logic and criteria that organize methodology and methods" (Salkind, 2010, 1158). Although in many studies the theoretical perspective remains hidden in research and is only implicitly perceptible in the working process, it influences the development of the work and should therefore be identified and explained (Tashakkori and Creswell, 2007a).

Tashakkori and Creswell (2007a) highlight two important aspects related to theoretical perspectives: on the one hand, QUAN, QUAL, and MIX approaches are not inherently linked to any perspective. On the other hand, studies do not need to be based on a single theoretical perspective. According to the same assumption of mixed methods approaches, it is possible in the same study to combine multiple perspectives to take the best advantage of each of them.

Yazan (2015) gives the example of methodologist Robert Stake and his recommendation for the combined use of constructivist and existentialist perspectives for the orientation of qualitative case study research. For this research, two theoretical perspectives have been chosen: (i) the constructivist perspective and (ii) the pragmatic perspective.

	interpretivism	pragmatism
ontology	constructivism	symbolic realism
empirical focus	beliefs (social constructed cognition)	actions and changes
types of knowledge	understanding	constructive knowledge
role of knowledge	interesting	useful for action
types of research	field study	inquiry
data generation	data through interpretation	data through assessment and intervention
role of researcher	engaged in understanding	engaged in change

Table 17. Differences between interpretivism and pragmatism—adapted from Goldkuhl (2012)

According to Hatch (2002), constructivism is a theory of knowledge embedded in the interpretive paradigm, and its principle is the impossibility of humans knowing the world as an objective fact. From an ontological perspective, constructivism posits that reality is not a given that presents itself to humans as something evident and immediately perceived through empirical experience, but a socially produced construction, that is, a concrete elaboration. Thus, knowledge is not discovered but constructed (Stake, 1995).

In this sense, the constructivist perspective argues for the existence of multiple subjective realities constructed by individuals from their experience with the world in a specific circumstance—as Guba and Lincoln argue, realities are comprehensible in the form of abstract mental constructions that are experientially based, local, and specific (in Hatch, 2002). For constructivists, scientific knowledge is not a simple reflection of reality but the result of a process of organization and structuring of experiential data by individuals to understand them.

From an epistemological perspective, Hatch (2002) and Salkind (2010) characterize the constructivist perspective according to five aspects:

(i) individuals symbolically construct knowledge, which is not objective or external to them. Constructivist researchers focus on these individual constructions;
(ii) the comprehension of reality is rooted in conventions rather than neutral observation;
(iii) truth is not absolute but the result of social deliberation;
(iv) political, historical, or cultural context is crucial in understanding objects or phenomena;
(v) in a constructivist study, the researcher and participants engage together in the process of constructing subjective knowledge about reality, termed as co-construction by Hatch (2002).

From a methodological perspective, constructivist studies are typically embedded in naturalistic qualitative research strategies (Hatch, 2002), using research strategies such as case studies, comparative studies, ethnographic studies, grounded theory, biographical studies, and phenomenological studies. The methods of data collection, recording, analysis, and interpretation used are mainly passive or participatory observation, interviewing, and documentation, which privilege the extended interaction of the researcher with participants in real-life settings and detail in recording contextual specification.

The rigorous, detailed contextual specification is what allows for the "transferability" of qualitative-constructivist studies. This quality replaces the typical generalizability found in quantitative-positivist studies (Yin, 1984). Denzin and Lincoln explain that terms such as credibility, transferability, dependability, and confirmability replace the usual positivist criteria of internal and external validity, reliability, and objectivity (in Hatch, 2002).

Inductive logic, or a combination of both inductive and deductive reasoning, is typically favored as an alternative to purely deductive logic. Similarly, adopting a holistic approach is emphasized as a prerequisite for tackling the complexity inherent in social phenomena, serving as an alternative to reductionist objectivism. In this approach, the theory is formulated based on the study of reality, reversing the traditional process.

The pragmatic perspective, encompassing various sub-perspectives like functional pragmatism, referential pragmatism, and methodological pragmatism (Goldkuhl, 2012), prioritizes practical application over theory. It also emphasizes the importance of the consequences and effects of actions over their underlying principles and assumptions.

According to Goldkuhl (2012), pragmatic ontology is precisely defined based on the concepts of action and change. For pragmatists, action is considered both the core of society and the instrument or intermediary for altering existence, alongside reason (instrumental). Therefore, the world is transformed through a combination of reason and action, highlighting an inseparable connection between human understanding and human activity (Goldkuhl, 2012).

From an epistemological point of view, as Dewey (in Feilzer, 2010) refers, pragmatism departs from both the objectivist and subjectivist paradigms, in that it does not aim to discover the truth, whether it is unique and objective or multiple and subjective. According to the pragmatic perspective, it is not important to have an exact understanding of reality or how things are in themselves; what matters are the consequences or usefulness of knowledge (Feilzer, 2010). In this sense, pragmatism is also referred to as instrumentalism (Abbagnano, 1984).

From a methodological point of view, pragmatism also tends to move away from the objectivism-subjectivism dichotomy, as it is not linked to specific methods or types of data. Pragmatism is usually associated with mixed methods approaches, rather than quantitative or qualitative approaches (Tashakkori and Creswell, 2007b). Pragmatic researchers, as Tashakkori and Creswell (2007b) state, emphasize the research problem first and then choose the most appropriate methods and techniques to address it.

Chapter 4 Three schools of architecture

4.1 Presentation

4.1.1 Overview

The results that we will present in this chapter are organized into three sections, following the three units of analysis. In the first section, Context, we present the initial set of findings related to the definition and organization of the design studios. Although these results are not directly related to our primary research questions, they provide valuable insights into the learning environment and approach to design education. We begin by examining the class setting's key aspects, including the number of instructors, teaching assistants, and guests. We then explore the specifics of the exercises assigned in each design studio and identify any patterns or trends in the approach to design education. Finally, we examine general aspects related to the representation and work processes of students and their impact on the learning outcomes.

In the second section, Design Process, we present our findings on the working process and the produced representations of the students in the design studios. We explore the various forms of representation used by students, including digital and analog mediums, and their interplay. We then analyze the presence and modes of use of physical models and prototypes in design studios. Subsequently, we consider the role of freehand drawing in the design process, including its strengths and limitations, and how students improve their skills in this area. Finally, we address some of the primary difficulties that students face in the design process, including specific challenges related to the use of representation tools.

In the third section, Design Critiques, we present findings specifically focused on the use of representations in design critiques, a crucial moment in the design studio teaching model. We describe the general process of design critiques and provide background information about each of the schools we studied to contextualize our findings within their respective educational contexts. We analyzed the data on how both instructors and students use representation during these critiques to identify patterns or trends. We examine the modes of interaction between instructors and students during design critiques, including how instructors provide feedback and how students respond. Furthermore, we explore the different ways in which instructors and students incorporate freehand drawing into design critiques and the benefits and challenges associated with this.

Figure 5. Types of design classes observed, MIT, 2022

4.1.2 Fieldwork

The fieldwork conducted during this research was a key component in understanding the design education practices in the three different case studies. At POLIMI, the fieldwork comprised three separate phases: from November 2019 to February 2020, May 2021 to July 2021, and October 2021 to February 2022. These different phases allowed for a comprehensive understanding of the design education practices at different times of the year and in different academic semesters. At FAUP, there was one fieldwork period from November 2020 to March 2021, which allowed for a deeper understanding of the practices during a single academic year. At MIT, there was one fieldwork period from March 2022 to September 2022.

The focus of the fieldwork was the design studios, where 25 classes were observed at POLIMI, 22 at FAUP, and 21 at MIT. The aim was to observe students from different academic years in order to recognize the situation in these three schools in terms of student backgrounds and education, as well as the demands of instructors and curricula. The main types of classes observed were design critiques, but also included pin-up sessions, mid-term reviews, final presentations, and theoretical classes (figure 5).

`	POLIMI	FAUP	MIT
critiques	16 64%	19 73%	12 57%
mid-term	1 4%	1 4%	5 24%
final presentations	6 24%	4 15%	4 19%
theoretical	2 8%	2 8%	
total	25 100%	26 100%	21 100%

Table 18. Types of design classes attended

In addition to the in-person fieldwork, remote classes were also attended. Particularly during the second wave of the Covid-19 pandemic, between November and March 2021, there was the possibility of systematically attending remote classes at POLIMI and FAUP. This provided a unique opportunity to gain insights into the online teaching modality in design education. The remote classes attended included mid-term or final exams, as well as conversations with instructors and students. Out of these 68 design studios, the majority (72%) were conducted in person, which involved students attending the studio classes physically in a traditional classroom setting.

On the other hand, 28% of the design studios were conducted remotely, where students and teachers interacted virtually via digital communication platforms such as Zoom or Microsoft Teams. This mode of instruction provided flexibility, convenience, and access to a wider range of resources. However, it also posed challenges such as technical difficulties,

limited personal interaction, and the need for effective time management. Finally, 7% of the design studios were conducted in a hybrid mode, which involved a combination of in-person and remote instruction. This mode allowed for flexibility and convenience while maintaining some level of personal interaction and collaboration. However, it also required careful planning and coordination to ensure that the different modes of instruction complemented each other and were effectively integrated.

In addition to design studios, a range of other courses was also observed to help understand the context of each school. Specifically, at FAUP, systematic attendance was given to drawing classes to better understand the teaching of representation (see 5.2. Drawing and Perception). Furthermore, a variety of theoretical courses, such as architectural theory, history, and urbanism, were also observed. These courses were chosen to provide a broader understanding of the overall curriculum and academic context of the schools. During the fieldwork, semi-structured conversations and interviews were conducted with both instructors and students. Most of these conversations occurred during or immediately after observing classes, allowing for real-time insights and reflections..

	POLIMI	FAUP	MIT
design courses	25 57%	22 43%	21 48%
other courses	4 9%	15 29%	15 34%
conversations with instructors	6 14%	10 20%	4 9%
conversations with students	9 21%	5 10%	4 9%
total	44 100%	52 100%	44 100%

Table 19. Courses attended and conversations with instructors and students

4.2 Results

4.2.1 Context

This section presents the initial findings on the context regarding the design studios, which provide insights into the organizational structures used. The analysis includes the class setting, exercises assigned, and representation and work processes of students. The aim of this section is to identify any patterns or trends in the approach to design education and how instructional design and teaching methodologies affect student outcomes.

Class settings

The first factor that we analyzed is the number of instructors in the design studios of three different schools. At POLIMI, we observed that most design studios have two instructors, which accounted for 56% of the total. The courses with one instructor were the second most common, representing 40% of the cases. There were only a few design studios with three or more instructors, with just one case observed at POLIMI.

In contrast, at FAUP and MIT, most design studios have only one instructor per class. At FAUP, 95% of the design studios had only one instructor, indicating that the school may prefer a more focused approach to teaching design. Similarly, at MIT, 81% of the design studios had only one instructor, although there were slightly more cases with two instructors compared to FAUP. In both schools, there were only a few design studios with three or more instructors, with just one case observed at FAUP and none at MIT.

	POLIMI	FAUP	MIT
1	10 40%	21 95%	17 81%
2	14 56%		4 19%
3		1 5%	
4	1 4%		
total	25 100%	22 100%	21 100%

Table 20. Number of instructors in design studios

The presence of teaching assistants and their number are important factors to consider when comparing different schools. In this context, the passage highlights that while FAUP does not have assistants in the design studios, the other two schools, POLIMI and MIT, have assistants in almost all courses. Moreover, the distribution of assistant numbers across these schools is not uniform. POLIMI exhibits the most diverse distribution, with a prevalence of one assistant per course (38%), followed by two assistants (29%), three assistants (25%), and occasionally five or eight assistants. In contrast, MIT predominantly employs one assistant per course (65%), followed by two assistants (35%).

It is also relevant to note that teaching assistants in these schools are typically undergraduate students, often two years ahead of the design studio they are assisting. While newly graduated students or PhD candidates may occasionally serve as teaching assistants, they are less common.

	POLIMI	FAUP	MIT
1	9 36%		11 52%
2	7 28%		6 29%
3	6 24%		
5	1 4%		
8	1 4%		
n	1 4%	22 100%	4 19%
total	25 100%	22 100%	21 100%

Table 21. Number of assistants in design studios

In terms of the presence of guests in design studios, FAUP does not frequently bring in outside guests for their classes, with only one instance observed across all their courses. In contrast, both POLIMI and MIT have a much higher rate of guest presence, with guests appearing in almost half of the courses at each institution. These guests are typically invited to serve as reviewers during regular classes, mid-term reviews, or as jurors during final presentations. Occasionally, they may also be asked to give a lecture. Notably, while the guests at POLIMI are mainly architects with experience in architectural practice, instructors from other schools, or researchers, at MIT, about half of the guests are students who are more advanced in their studies, fulfilling a role similar to that of teaching assistants.

	POLIMI	FAUP	MIT
1	8 32%	1 5%	3 10%
2	1 4%		
3	3 12%		7 35%
4			1 5%
n	13 52%	21 95%	10 50%
total	25 100%	22 100%	21 100%

Table 22. Number of guests in design studios

Exercises and briefs

The purpose of this section is to thoroughly examine and analyze the various factors that distinguish the design studio exercises at the three schools of architecture, in order to gain a better understanding of their unique approaches and perspectives. The first factor we examine is the nature of the exercises at each school, which can be classified as analytical, synthetic, or mixed. Analytical exercises focus on the analysis of existing architectural or urban design works, while synthetic exercises involve the creation of new designs. Mixed exercises comprise a combination of analytical and synthetic approaches, where different phases of the same exercise can have distinct natures.

At POLIMI, most exercises (68%) are of mixed nature, with a significant emphasis on analytical exercises (24%), where the focus is exclusively on analytical exercises, such as those related to reference architecture precedents, the work of important authors, or large-scale historical or contemporary architectural or urban interventions. On the other hand, FAUP focuses almost exclusively on synthesis exercises, with 95% of the exercises involving a design or urban project. In this approach, the analysis of existing works is integrated into the design process and does not have autonomy, except for a few exceptions. At MIT, most exercises are of mixed nature (52%), followed by synthesis exercises (43%).

Additionally, at POLIMI and MIT, requesting a dossier from students to accompany their design panels and models is common practice. The dossier serves to support the design proposal, emphasizing the importance of a theoretical, historical, and sometimes critical foundation for the students' proposals. In contrast, this practice is relatively rare at FAUP.

	POLIMI	FAUP	MIT
analytical	6 24%		1 5%
synthetical	2 8%	21 95%	9 43%
mixed	17 68%	1 5%	11 68%
total	25 100%	22 100%	21 100%

Table 23. Nature of design exercises

The second aspect to consider pertains to the exercise briefs in design studios, focusing specifically on the propositional or synthetic exercises. In all three schools, a written brief is always provided, but while the briefs from POLIMI and MIT do not include a detailed program for the design, FAUP's brief always contains this program, which includes the number and types of spaces, their area, or necessary infrastructure.

In relation to synthetic exercises, we consider the context or location of the intervention, distinguishing between real or imaginary contexts and whether it is nearby or visitable. In this regard, POLIMI shows a more even distribution across different categories, with the "real and nearby" category having the most occurrences (44%), followed by "real and visitable" (32%) and "real" (16%). There are also exercises in the "no context" category, but these are rare. At FAUP, exercises always have a real context and are always nearby, in the categories of "real and nearby" (55%) and "real and visitable" (45%). Finally, at MIT, we see a higher incidence of the "real and visitable" category (40%), followed by "real and nearby" (30%) and "real" (30%). We can see how FAUP stands out by focusing on nearby and visitable locations of intervention so that students can visit the site, which is a point highlighted by most instructors at the school.

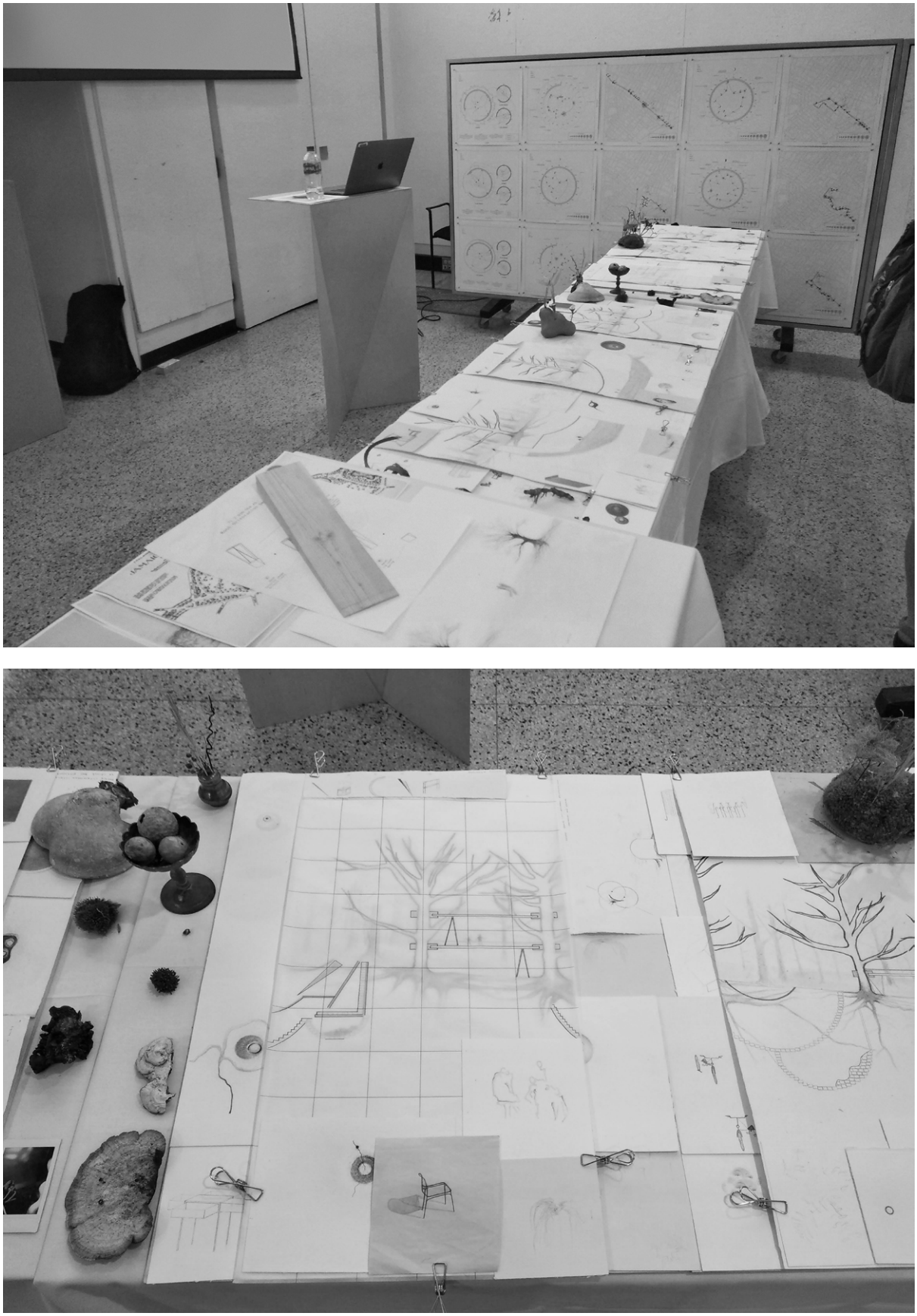


Figure 6. Example of a non-architectural exercise in a design studio, MIT, 2022

One interesting aspect of MIT's design studios is the inclusion of "non-architectural" programs, which means that approximately half of the courses observed focus on the development of a design object or something other than architectural design (figure 6).

	POLIMI	FAUP	MIT
no context	2 8%		
real	4 16%		3 30%
real and visitable	08 32%	10 45%	04 40%
real, visitable, and near	11 44%	12 55%	03 30%
total	25 100%	22 100%	10 100%

Table 24. Different contexts in design exercises

Modalities

An aspect worth considering is the modalities of the design studio exercises, whether they are completed individually or in groups. At POLIMI, group work is prevalent, with 92% of courses being completed collaboratively. In contrast, FAUP has a prevalence of individual work, with 95% of courses completed independently. MIT falls somewhere in the middle, with a tendency toward individual work at 67% but a significant proportion of group work at 33%.

	POLIMI	FAUP	MIT
group	22 92%	1 5%	7 33%
individual		21 95%	14 67%
both	3 8%		
total	25 100%	22 100%	21 100%

Table 25. Modalities in design exercises

When it comes to the number of students per group, each of the three schools has its unique approach. At POLIMI, where group exercises are frequently assigned, we see a wide range of group sizes and compositions. In particular, groups with four students are the most common (46%), followed by groups with three (33%) and five (21%) students. This distribution indicates that the faculty at POLIMI places an emphasis on the value of collaborative work and encourages students to engage in group exercises regularly. On the other hand, at FAUP, group exercises are not emphasized, and there is only one recorded instance of a five-member group. At MIT, where some group work is assigned, all groups consist of only two members.

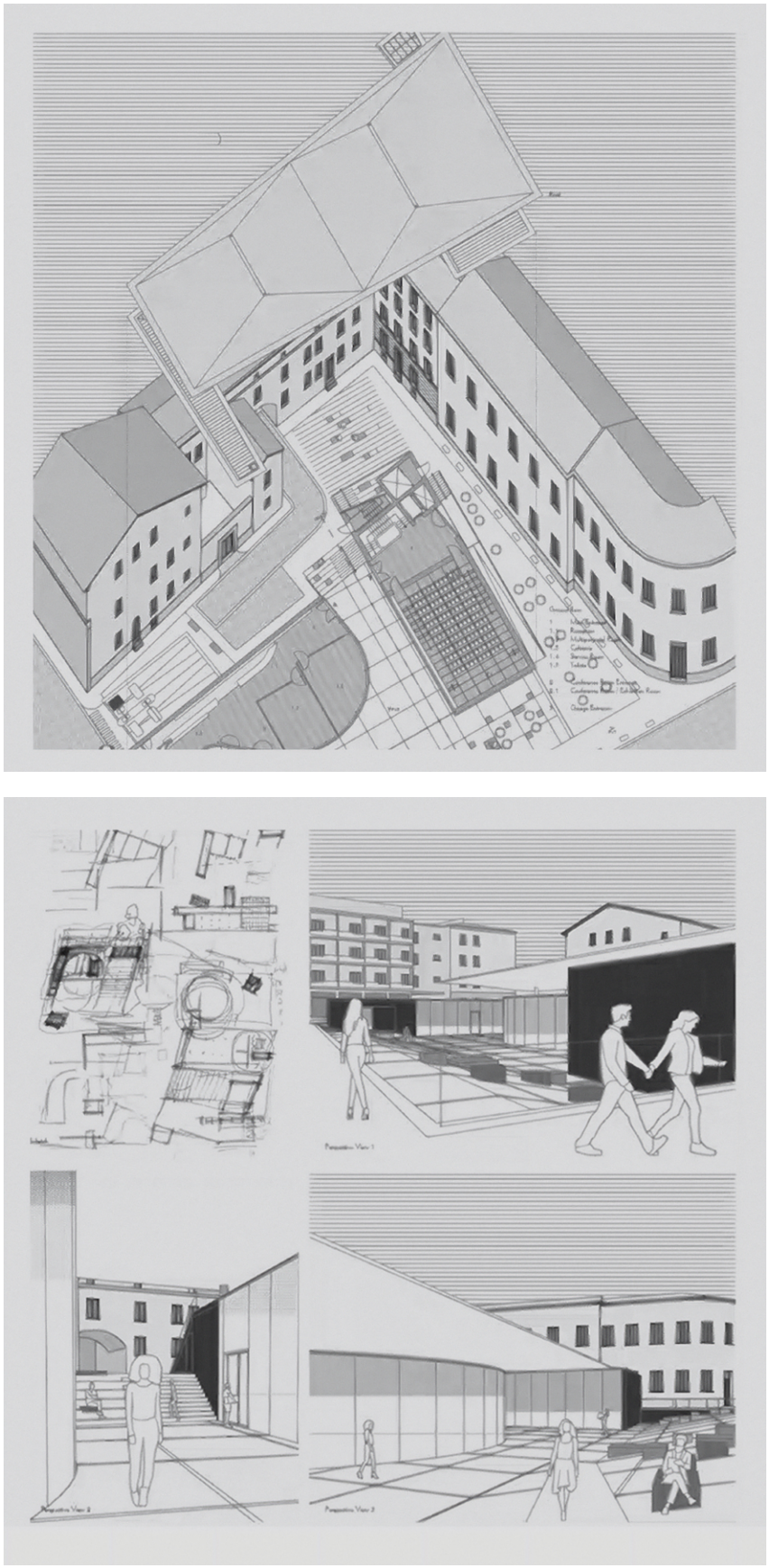


Figure 7. Mixed media representations, POLIMI, 2021

	POLIMI	FAUP	MIT
2			7 100%
3	8 33%		
4	11 46%		
5	5 21%	1 100%	
total	24 100%	1 100%	7 100%

Table 26. Number of students in group modalities

4.2.2 Design process

This section presents the findings of a research study on the working process of students in three schools, exploring their use of various forms of representation, including digital and analog mediums, and the use of physical models and prototypes in design studios. It also delves into the role of freehand drawing in the design process and the functions assigned to it by students, as well as identifying the primary difficulties faced by students in the design process, including challenges related to the use of representation tools.

External representations

One factor that we considered in the representations produced by students, both in their work process and in the representations for review, is the balance between analog and digital media. Overall, the data show that most of the representations produced fall into the mixed category, which means that they have both an analog and digital component, accounting for 72% of the total. The remaining representations are predominantly analog (19%) or predominantly digital (9%).

Looking at the specific cases, we can see that POLIMI and MIT have a similar distribution, with over 80% in the mixed category (figure 7), with the remainder distributed between analog and digital in the case of POLIMI or only digital in the case of MIT. FAUP, on the other hand, differs, with a lower percentage of representations falling into the mixed category (33%) and a strong incidence of analog representations (67%). Here, there is a noticeable difference compared to the other two schools, with a very significant presence of analog representation media (figure 8).

Overall, and this is an aspect that interested us to verify, the analog component is not completely absent in the work processes of the three schools, although it is significantly diminished compared to digital instruments. In part, as we saw earlier, this is due to strategies or restrictions imposed by the instructors, as in the case of FAUP, where the students are not allowed to use digital media in the first two years.

Figure 8. Analog media representations, FAUP, 2022

	POLIMI	FAUP	MIT
analogue	1 4%	10 67%	
digital	2 9%		3 13%
both	20 87%	5 33%	17 85%
total	23 100%	15 100%	20 100%

Table 27. Representation media in design process

After analyzing the overall media use by students, it is important to identify the most frequently used support types. A general analysis shows that digital media is the most popular among students, followed by plain paper. However, there are some variations in the proportion of media usage among the three schools.

At POLIMI, digital and plain paper media are the most used (both at 33%), followed by tracing paper (16%) and personal notebooks (11%). At FAUP, analog media types such as plain paper, tracing paper, and personal notebooks are used in equal proportions (27%), followed by digital media slightly below (19%). At MIT, digital media is the most prominent (33%), followed by plain paper and personal notebooks used equally (28%). Tracing paper is also used to some extent (11%) at MIT.

	POLIMI	FAUP	MIT
cardboard	4 7%		
digital	18 33%	10 19%	20 33%
notebook	6 11%	14 27%	17 28%
plain paper	18 33%	14 27%	17 28%
tracing paper	9 16%	14 27%	7 11%
total	55 100%	52 100%	61 100%

Table 28. Support types in design process

One other factor that we considered was the types of representations produced by the students. Overall, we observed that technical representations were the most common type across all three schools, followed by freehand drawings, CAD perspectives, and renderings. At both POLIMI and MIT, we found a wide variety of forms of representation, with a balanced distribution among the different types, making it difficult to identify a clear trend. However, at FAUP, there was a significant emphasis on freehand drawing compared to the other schools (figure 10), accounting for the highest percentage of representation (42%), even surpassing technical representations (29%). On the other hand, FAUP had a lower diversity of forms of representation than the other schools.

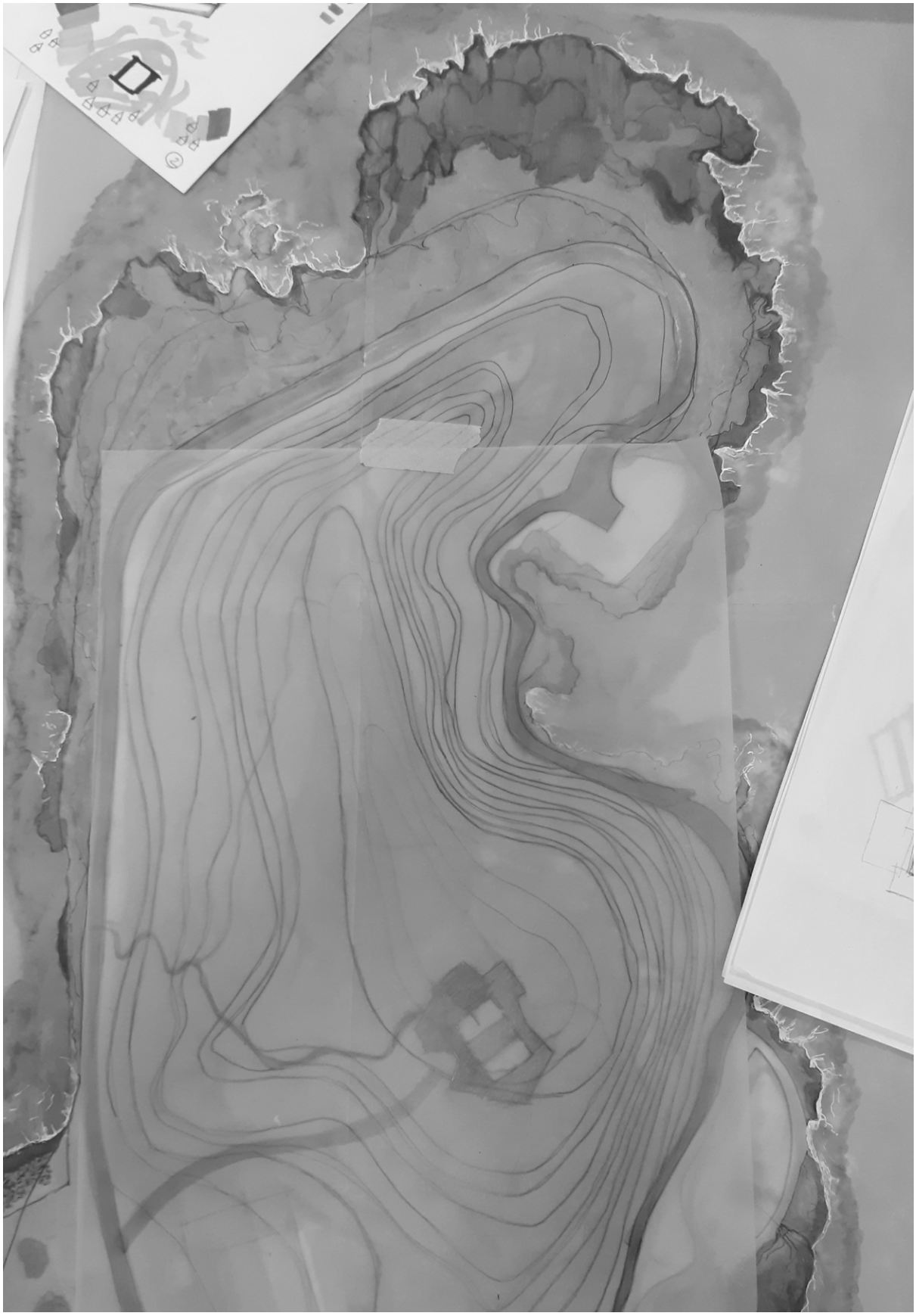


Figure 9. Student's drawing with multiple layers of tracing paper, POLIMI, 2021

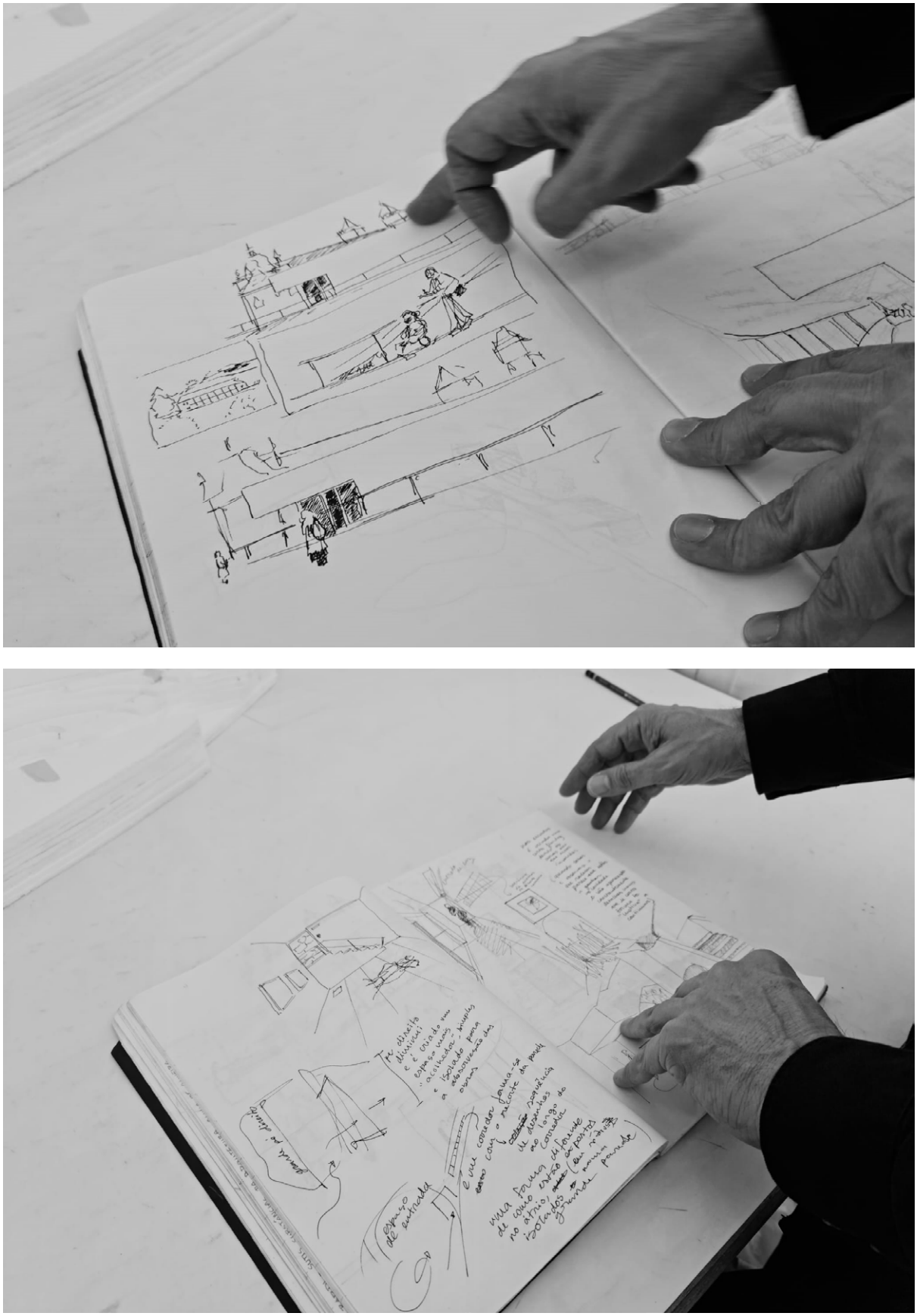


Figure 10. Student's graphic notebook, FAUP, 2022

Figure 11. Student using tracing paper on a CAD representation, FAUP, 2022

	POLIMI	FAUP	MIT
collage	8 7%		
freehand drawing	20 17%	19 42%	17 16%
perspective	20 17%	8 18%	13 12%
photo	16 14%		11 10%
render	19 16%	4 9%	16 15%
scheme	11 9%	1 2%	20 16%
technical representation	23 20%	13 29%	17 16%
video	1 1%		12 11%
total	118 100%	45 100%	106 100%

Table 29. Forms of representation in design process

The last factor we will consider is the dynamic or static nature of these representations. As mentioned earlier, what determines whether an external representation is dynamic is its ability to enable design moves (Goldschmidt 2014), while a static external representation will not produce any movement in the design.

By examining these data, when combined with those presented above, we can establish a relationship between the dynamism-staticity of the external representations and the support or medium used, whether predominantly analog or digital, as well as the types of representations produced. This enables us to infer the functions assigned to external representations in the three schools, whether primarily serving the development and process of the design, mainly for its communication and visualization, or other purposes.

Therefore, we categorize the design studios observed into three categories based on the prevalence of representations with dynamic, static, or mixed characteristics among the students in each class. Overall, we see that the mixed category is the most prevalent in all three schools, followed by the static and, lastly, the dynamic, with the latter being the least observed. Interestingly, the distribution of categories in the three schools is quite different.

Starting with POLIMI, we see a prevalence of static-type representations (61%), followed by mixed (30%). At FAUP, there is a greater distribution, with a prevalence of dynamic representations (50%), followed by static (30%) and mixed (20%) (figure 11). Finally, at MIT, there is a high incidence of the mixed category (75%), followed by static (25%).

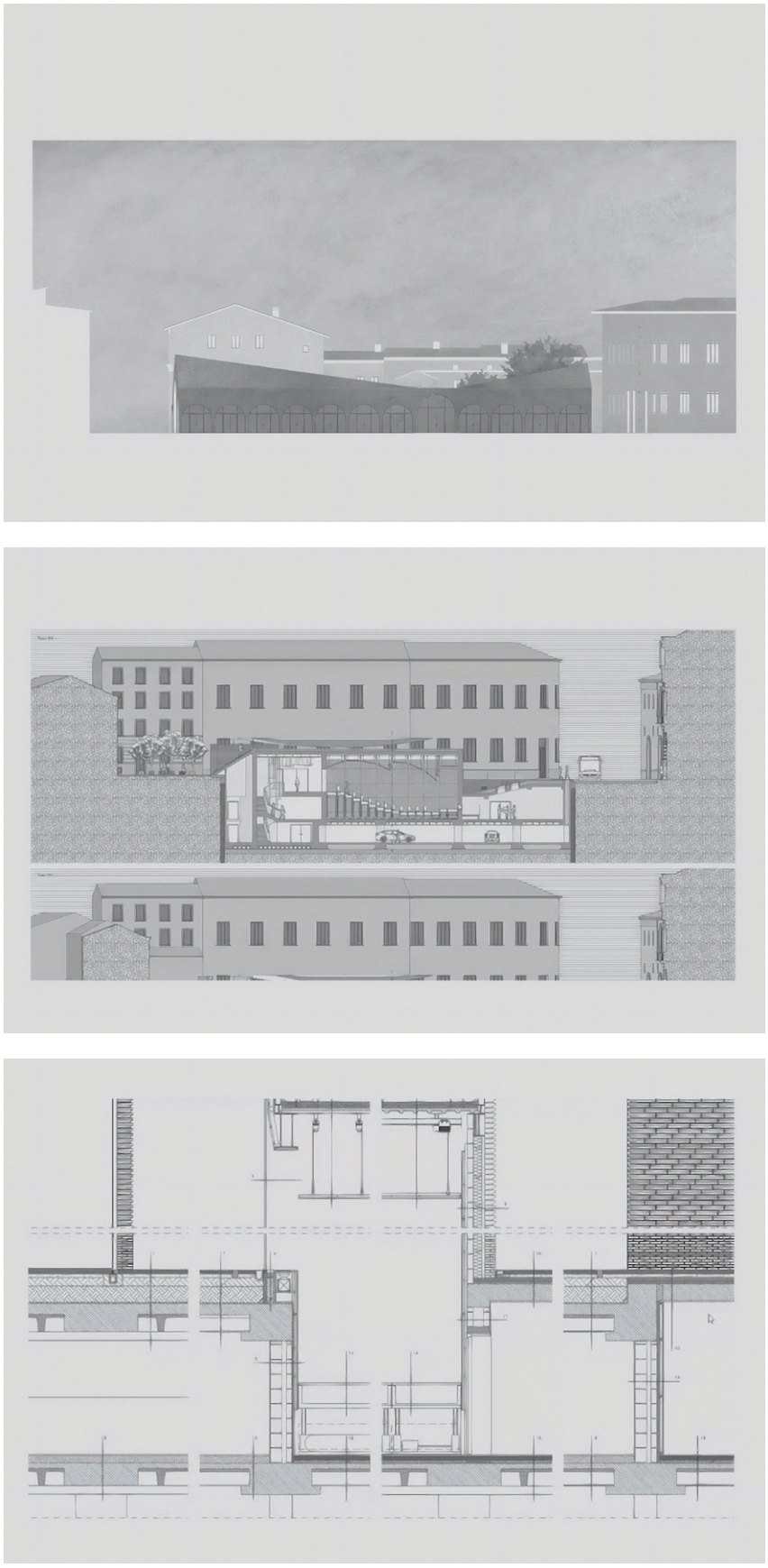


Figure 12. Rigorous representations following a hybrid style, POLIMI, 2021

	POLIMI	FAUP	MIT
dynamic	2 9%	10 50%	
static	14 61%	6 30%	5 25%
both	7 30%	4 20%	15 75%
total	23 100%	20 100%	20 100%

Table 30. Nature of external representations in design process

Rigorous representations

This set of results focuses specifically on the rigorous representations produced by the students. Firstly, we will examine the style of these representations, distinguishing three categories: (i) if they are purely technical representations, CAD-based, and therefore focused on informing design; (ii) if they are stylized representations, focused less on the technical information of the proposal and acquiring an autonomous value—realistic textures, elements such as trees or human figures are added; (iii) if they are hybrid representations, where the two previous styles are mixed.

At POLIMI, there is a more balanced distribution among these three categories compared to the other two schools, with stylized representations occurring most frequently (41%), followed by technical representations (31%) and hybrids (29%) (figure 12). At FAUP, there is a clear preference for technical representations (76%), with hybrids occurring much less frequently (20%), and stylized representations having almost no relevance (4%). Finally, at MIT, we see that stylized (48%) and technical representations (42%) occur almost equally frequently, with hybrids having a negligible occurrence (9%).

	POLIMI	FAUP	MIT
technical	15 31%	19 76%	14 42%
stylized	20 41%	1 4%	16 49%
hybrid	14 29%	5 20%	3 9%
total	49 100%	25 100%	33 100%

Table 31. Styles of technical representations in design process

The previous data allow for a more detailed analysis when we consider each design studio and observe whether there is a tendency to focus on only one of the previously mentioned categories (i.e., technical, stylized, or hybrid) or if there are multiple styles within the same class. There is a clear distinction between the three schools in this regard. At POLIMI, multiple styles within the same design studio prevail (73%). This means that the students in these classes are encouraged to explore different styles and techniques, allowing for a more

Figure 13. Student's physical model, MIT, 2022

diverse range of results. This approach can lead to a more creative and innovative output, as students are given more freedom to express themselves.

On the other hand, at FAUP, the prevalence is almost the same for single styles (75%). This means that the design studios in this school tend to focus more on a specific style or technique, which can limit the students' creativity and potentially lead to less diverse results. At MIT, there is a nearly equal distribution between multiple and single styles, with a slight majority for single styles (53%). This suggests that the design studios in this school strike a balance between encouraging exploration of different styles and techniques while still having a clear focus or direction in the design process. This approach can lead to well-rounded and cohesive results.

	POLIMI	FAUP	MIT
single	6 27%	15 75%	10 50%
multiple	16 72%	5 25%	10 50%
total	22 100%	20 100%	20 100%

Table 32. Single and multiple styles of technical representations in design process

Physical models and prototypes

Our analysis will now focus on the physical models and prototypes created by students in design studios across the three schools in terms of quantity, production methods, materials, style, nature, and scales. We have made a deliberate decision to prioritize the analysis of physical models and prototypes due to their paramount significance in design studios, as they serve as a complementary form of representation (figure 13). As seen in the first set of results, it is common for design studios to produce physical models and prototypes, with an incidence rate ranging from 80–86%. This equivalence in incidence rate across the three schools is quite remarkable. It is worth noting that prototypes are an exclusive practice of MIT, with an incidence rate of 38%, slightly lower than that of physical models (43%).

	POLIMI	FAUP	MIT
model	21 84%	19 86%	9 43%
prototype			8 38%
none	4 16%	3 14%	4 19%
total	25 100%	23 100%	21 100%

Table 33. Presence of physical models and prototypes in design process

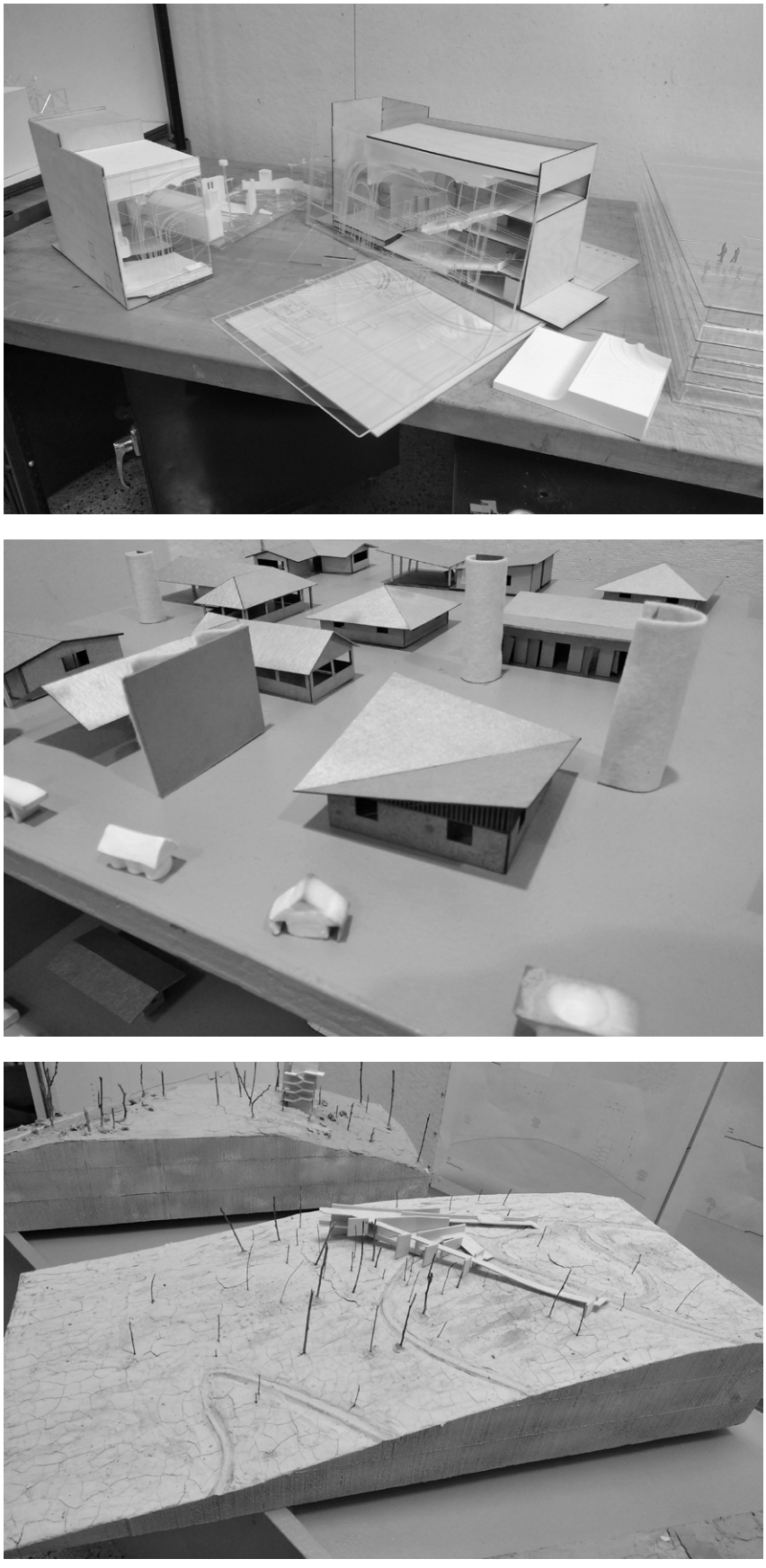


Figure 14. Different materials used for physical models, MIT, 2022

We will now examine the production of physical models and prototypes, considering whether they are handmade or digitally fabricated by students or support technicians. Our analysis shows that although students are increasingly utilizing automation resources, the overall relevance of handmade models remains higher than that of fabricated ones. Specifically, handmade models consistently achieve scores of 75% or higher across all three schools. Furthermore, it is noteworthy that there is currently no record of automation being utilized in the production of physical models within the design studios at FAUP.

	POLIMI	FAUP	MIT
automatized	5 24%		3 18%
handmade	16 76%	19 100%	14 82%
total	21 100%	19 100%	17 100%

Table 34. Automatized and handmade physical models and prototypes in design process

Considering the physical models and handmade prototypes, we have conducted a comprehensive analysis of the most commonly used materials for their production. Our findings reveal that traditional materials such as cardboard, Styrofoam, and wood remain the go-to choices for students, with some variations observed across different schools.

At POLIMI, cardboard emerges as the clear winner, with a usage rate of 67%. It is followed by wood (15%), acrylic (11%), and Styrofoam (7%). Meanwhile, at FAUP, students tend to choose between Styrofoam (61%) and cardboard (39%). At MIT, however, we observed a greater diversity of materials utilized, which is attributed to the production of prototypes and the experimentation with the characteristics of different materials. Despite this, cardboard and Styrofoam remain relevant in the overall landscape, with an incidence rate of 19%, only surpassed by metal at 24%.

It is worth noting that instructors often provide restrictions and suggestions for materials that students should use (see 4.2.1 Context: Modalities). For instance, the first-year design studios at FAUP frequently employ Styrofoam, while certain design studios at MIT use sheet metal. Overall, our analysis underscores the continued importance of traditional materials in the creation of physical models and prototypes, albeit with some notable variations in usage patterns across different institutions.

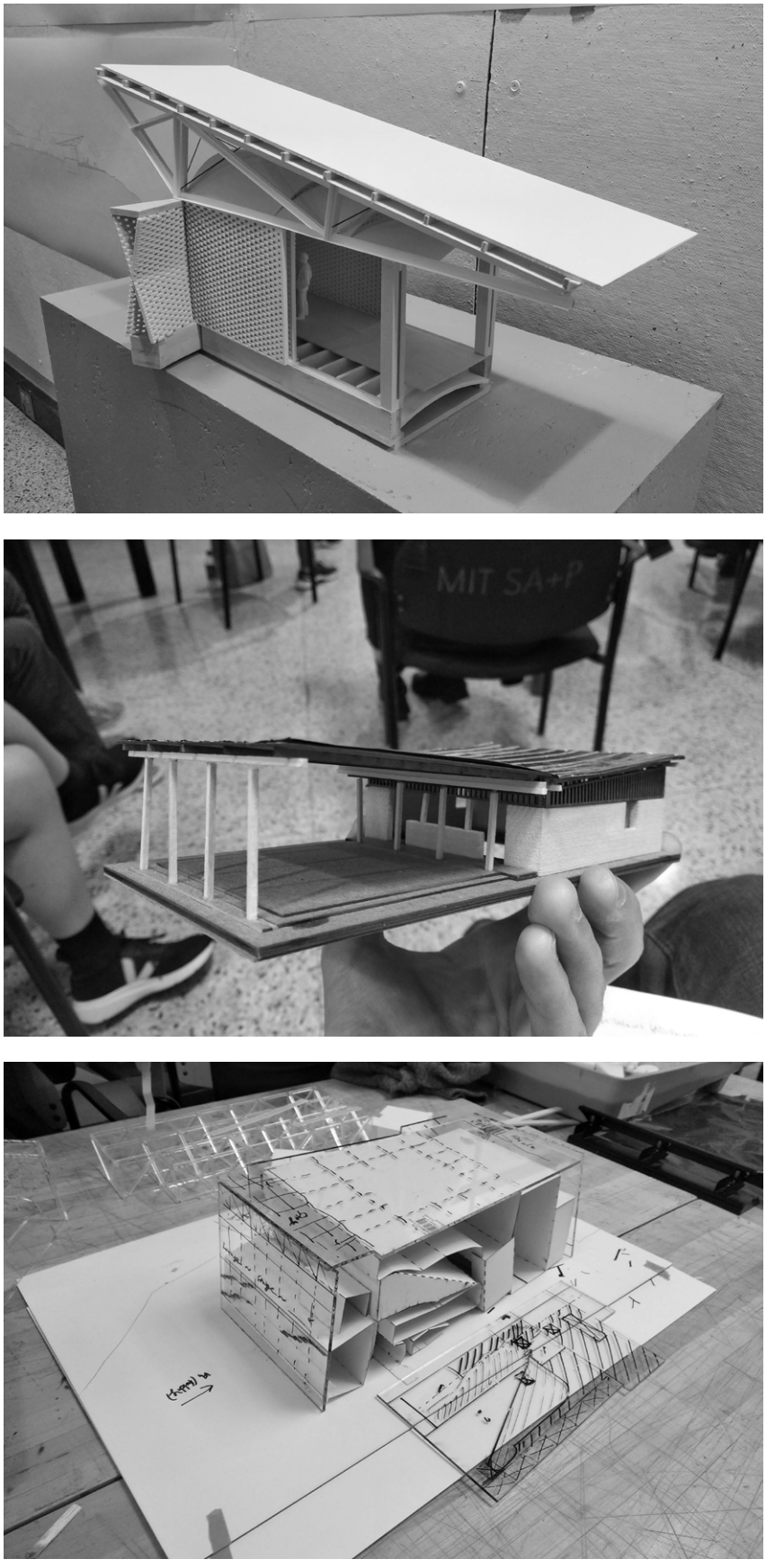


Figure 15. Different styles of physical models, MIT, 2022

	POLIMI	FAUP	MIT
acrylic	3 11%		10 17%
cardboard	18 67%	12 39%	11 19%
metal			14 24%
Styrofoam	2 7%	19 61%	11 19%
wood	4 15%		4 7%
others			9 15%
total	27 100%	31 100%	59 100%

Table 35. Materials used for physical models and prototypes in the design process

Concerning the styles of physical models, we have identified three main categories: (i) the abstract style, in which the architectural object and its context are represented in their most basic form, often employing only one material and one color; (ii) the realistic style, in which an attempt is made to reproduce the materiality of the architectural object and its context, highlighting the different construction materials, colors, etc.; (iii) the thematic style, in which the model itself gains a certain degree of autonomy in relation to the architectural object it represents—in some cases, these models even possess an interactive dimension, which is sometimes referred to as a toy model.

What we have found is that, across all three categories, the abstract style is the most frequently used. In contrast, the realistic style is the least relevant category in all three schools. Specifically, at POLIMI, the abstract style is highly relevant (61%), followed by the thematic style, which is also widely used (27%). At FAUP, only abstract style models were recorded. At MIT, there is an equal distribution between abstract and thematic style models (43%), followed by the realistic style with a residual presence (14%).

	POLIMI	FAUP	MIT
abstract	20 61%	19 100%	9 43%
realistic	4 12%		3 14%
thematic	9 27%		9 43%
total	33 100%	19 100%	21 100%

Table 36. Styles of physical models in design process

Another aspect that is relevant to our analysis of the different forms of representation (as described in section 4.2.2.1) is the nature of the productions themselves, specifically whether they are static, dynamic, or a combination of both. It is worth noting that, for the purposes of this analysis, we did not include prototypes in our evaluation of the physical models used in design studios. Our findings indicate that all three schools tend to have a

Figure 16. Dynamic physical model, FAUP, 2021

high incidence of static productions in relation to physical models. This suggests that students may face challenges in leveraging the full potential of physical models to inform their design decisions. This is a concern that has been raised by instructors across all three schools.

POLIMI and MIT both show very high proportions of static productions, with 90–100% of productions being static. This means that physical models are not used in a dynamic way but rather as static, physical representations of a design concept. In contrast, at FAUP, there is a more even distribution between static and dynamic uses of physical models. Specifically, 47% of design studios at FAUP use dynamic physical models, where physical models are used in a way that allows for exploration of different design possibilities and the ability to manipulate the model.

However, even at FAUP, the numbers of static (32%) and mixed (21%) productions are still substantial. This means that although there is a higher proportion of dynamic uses of physical models at FAUP compared to POLIMI and MIT, there are still a significant number of studios that primarily use physical models in a static way or a combination of static and dynamic ways.

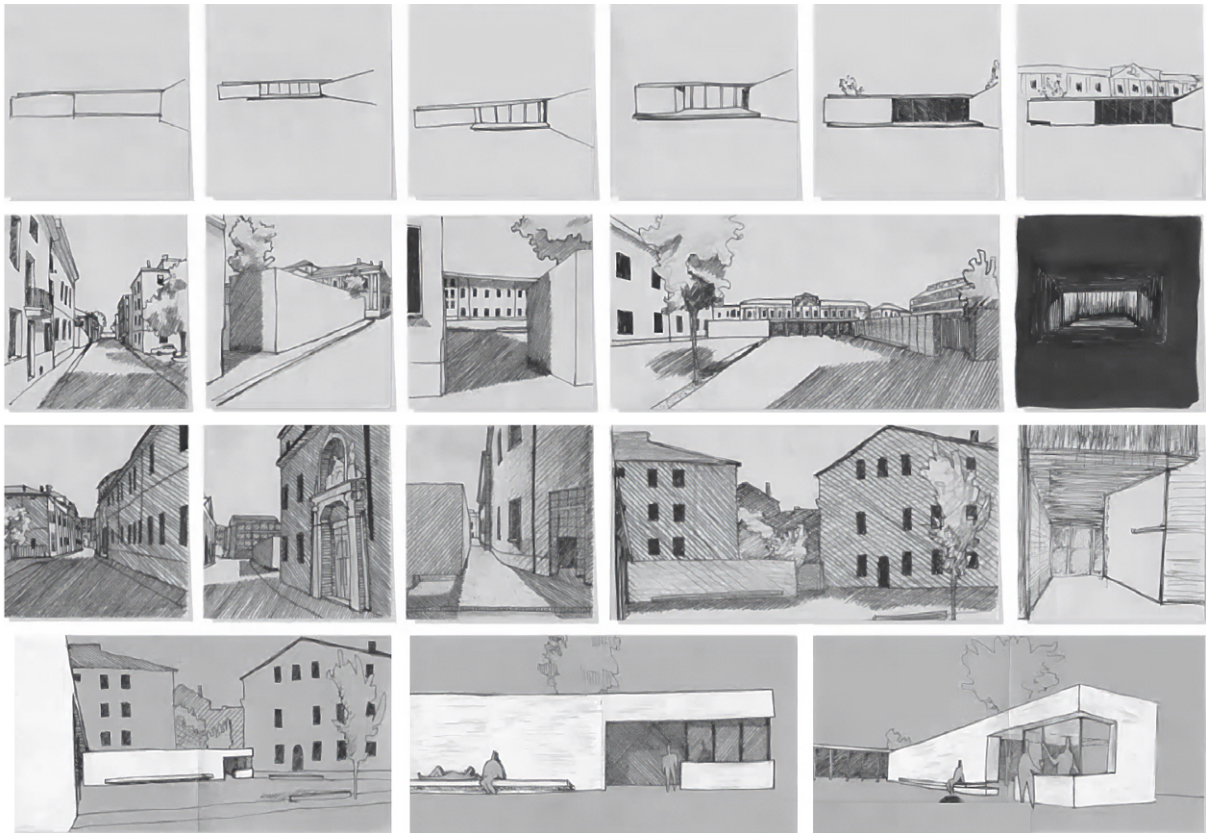
	POLIMI	FAUP	MIT
dynamic	2 10%	9 47%	
static	19 90%	6 32%	16 100%
both		4 21%	
total	21 100%	19 100%	16 100%

Table 37. Nature of physical models in design process

Freehand drawing

The objective of our analysis in this segment is to examine the utilization of freehand drawing by students in design studios. We will begin by examining the frequency at which it is used, considering the level of proficiency displayed. Then, we will delve into the functions of freehand drawing in design studios, the contexts in which it is utilized, and finally, the mediums employed.

Initially, it is clear that freehand drawing holds significant importance as a form of representation in the design studios under observation, with usage rates exceeding 85% across all three schools. While the highest incidence of freehand drawing in design studios is found in the first two years of the course at FAUP, due to it being a mandatory requirement set by instructors, the other institutions exhibit a more even distribution without any clear associations to specific academic years.



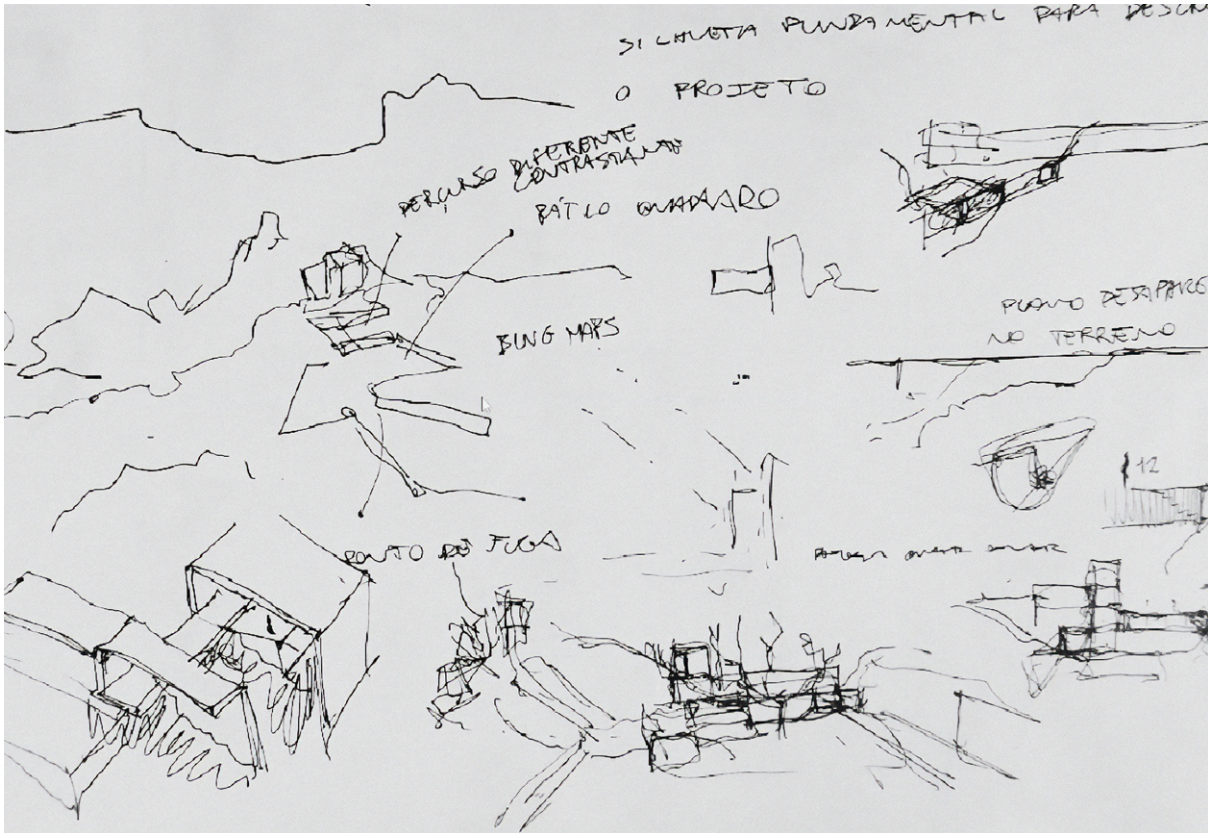


Figure 17. Student's notebook with an observational freehand drawing, POLIMI, 2021

Figure 18. Freehand drawing used for design presentation, POLIMI, 2021

	POLIMI	FAUP	MIT
y	20 87%	19 100%	17 85%
n	3 13%		3 15%
total	23 100%	19 100%	20 100%

Table 38. The presence of freehand drawing in design process

In order to better comprehend the frequency and importance of freehand drawing in design studios, a more in-depth analysis was conducted. The analysis involved categorizing the prevalence of freehand drawing into three distinct levels: (i) high; (ii) medium; and (iii) low. By establishing these categories, it was possible to examine the incidence of freehand drawing in a more nuanced and detailed way.

Firstly, at POLIMI, where freehand drawing has a high incidence rate of 87%, it is mostly categorized as low (75%). Only a minority of freehand drawing falls into the medium category, which accounts for only 20% of the total. Secondly, at FAUP, we observe a high level of freehand drawing use (53%), followed by a low level (26%). However, the medium category is used to a slightly greater extent, making up 21% of the total incidence rate. Finally, at MIT, we see no occurrence of a high level of freehand drawing. Instead, the vast majority falls under the medium category (76%). The remaining incidence rate of freehand drawing at MIT is classified as low, which accounts for only 24% of the total.

	POLIMI	FAUP	MIT
high	1 5%	10 53%	
medium	4 20%	4 21%	13 76%
low	15 75%	5 26%	4 24%
total	20 100%	19 100%	17 100%

Table 39. Frequency of freehand drawing in design process

We will now delve into how students utilize freehand drawing in design studios. It is important to clarify that we will not be discussing its use in design critiques, which will be addressed in the subsequent section. Instead, we will focus on how students utilize freehand drawing in the design process and in their representations. Upon analyzing data from the three schools, we have identified that the most prevalent use of freehand drawing is for presentation or communication, followed by its use as a design tool. However, the distribution of its usage across the three schools reveals a more nuanced perspective.

At POLIMI, the primary function assigned to freehand drawing is design presentation (figure 17), accounting for 64% of its usage. Its use as a design tool comes in second, with a

Figure 19. Freehand drawing used as a design tool, FAUP, 2021

significantly lower percentage of 21%, representing its utility as a means of executing design moves. Freehand drawing is also frequently used as an analysis or study tool, accounting for 14% of its usage.

In contrast, at FAUP, we observe a distinct pattern. The most common use of freehand drawing is as a design tool, accounting for 29% of its usage (figure 18), followed by observation and analysis, each with an equal rate of occurrence of 24%. Freehand drawing used for survey has a residual occurrence of 7%. Lastly, at MIT, freehand drawing is most commonly used as a design tool, accounting for 48% of its usage, followed closely by its use as an instrument for presentation, with a significant 39% of its usage.

	POLIMI	FAUP	MIT
presentation	18 64%	3 7%	12 39%
design	6 21%	12 29%	15 48%
observation		10 24%	2 6%
survey		7 17%	
analysis	4 14%	10 24%	2 6%
total	28 100%	42 100%	31 100%

Table 40. Functions of freehand drawing in design process

When considering the configurations of freehand drawing in the design process and the resulting productions of design students, it is notable that technical drawing, specifically plans, sections, and elevations drawn by hand, is the most frequently employed form. However, subtle variations in the prevalence of different freehand drawing configurations among different design schools do exist.

At POLIMI, technical representations and schemes are the most utilized freehand drawing configurations, each comprising 30% of the total, with axonometric drawings following closely behind at 25%. Conversely, at FAUP, perspectives represent the most recurrent freehand drawing configurations, constituting 42% of the total, with technical representations trailing at 29%. Finally, at MIT, schemes are the most frequently employed configuration for freehand drawing, with a prevalence of 35%, followed by technical representations at 31% and perspectives at 19%.

In summary, while technical drawing is the most widely used form of freehand drawing, the specific configurations utilized differ between design schools. POLIMI emphasizes technical representations and schemes, while FAUP places greater emphasis on perspectives. In contrast, schemes are the most prevalent configuration for freehand drawing at MIT.

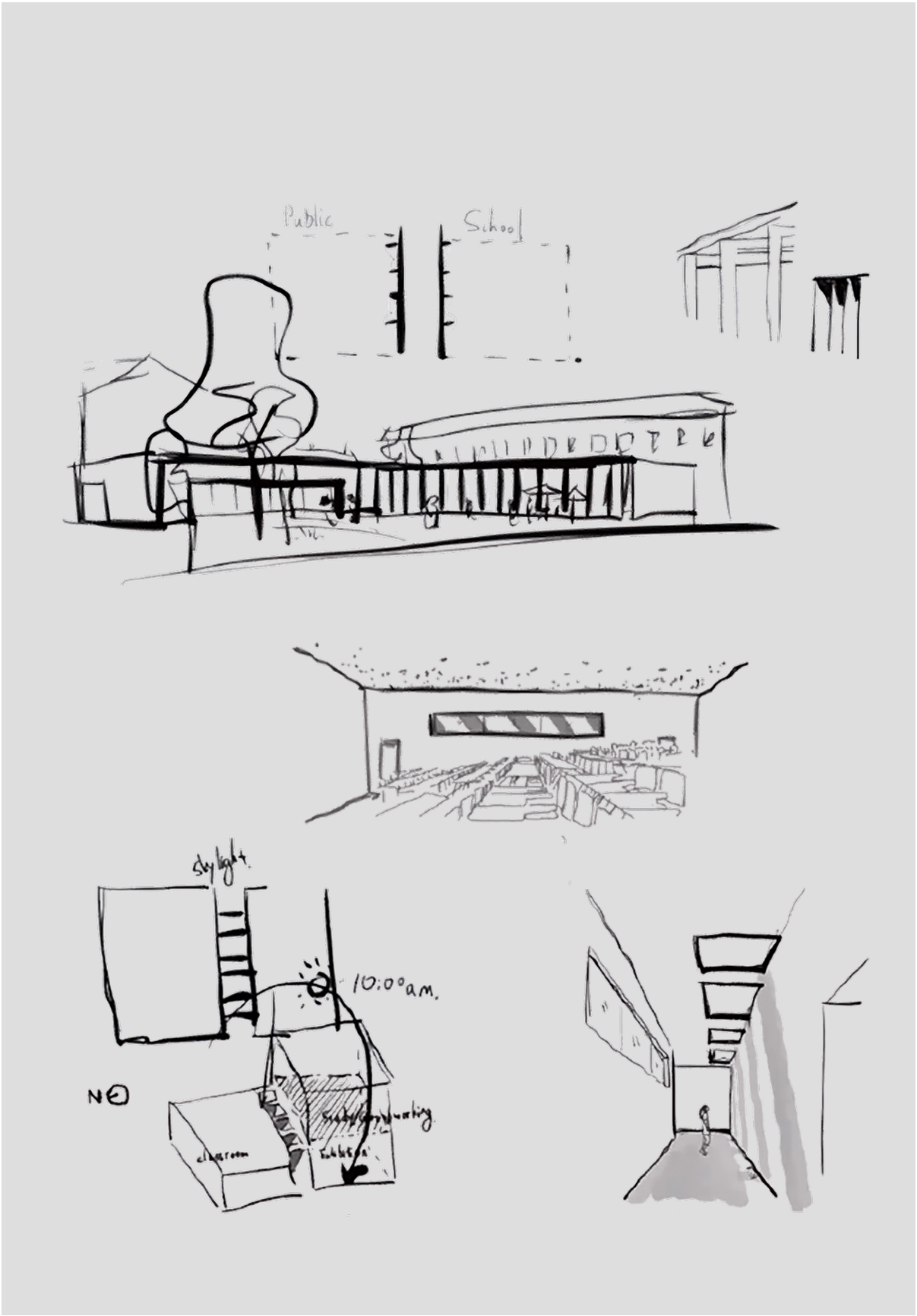


Figure 20. Digital freehand drawing, MIT, 2022

	POLIMI	FAUP	MIT
note	7 18%	5 11%	7 15%
perspective	7 18%	19 42%	9 19%
scheme	13 33%	8 18%	17 35%
technical	13 33%	13 29%	15 31%
total	40 100%	45 100%	48 100%

Table 41. Types of freehand drawing in design process

Finally, we will now consider the support used by students for freehand drawing in design studios. As expected, plain paper is the most used support in all three schools, followed by personal notebooks. This is evident at POLIMI and FAUP, with slightly different proportions, but also with a significant presence of tracing paper as a support (17% at POLIMI and 30% at FAUP). At MIT, we find that digital support (29%) is very close to the values of plain paper and personal notebooks (both at 33%).

In fact, unlike the other two schools, many students at MIT use a tablet as a replacement for physical notebooks, using them along with a stylus to take notes and draw as if they were doing it on a physical notebook. Students often use these digital, vectorized drawings as productions in design studios.

In summary, while plain paper is the most frequently used support for freehand drawing in all three schools, there are notable differences in the prevalence of other supports. Tracing paper is more commonly used at FAUP, while digital support is increasingly popular at MIT, where students utilize tablets and styluses as substitutes for physical notebooks. These digital drawings are often used as productions in design studios (figure 19).

	POLIMI	FAUP	MIT
cardboard	2 4%		
digital	1 2%		15 29%
notebook	6 20%	14 30%	17 33%
plain paper	17 57%	19 40%	17 33%
tracing paper	4 17%	14 30%	3 6%
total	30 100%	47 100%	52 100%

Table 42. Support types for freehand drawing in design process

Students' difficulties

In this segment, we will explore a range of issues that students encounter in design studios. We will begin by examining general challenges and then move on to difficulties related specifically to representation. One common challenge that students face across all three schools is the design process itself. Many students struggle with organizing their work, navigating different stages of the process, making decisions, and effectively utilizing representation in their designs. As we delve into the following section, we will take a closer look at these difficulties and explore potential solutions.

When comparing the three schools, it appears that POLIMI has a more evenly distributed range of difficulties among its students. The highest percentage is 17% for the "design process," and the lowest is only 4% for "contour line." However, other challenges such as "lack of construction" and "focus images" are also quite high, at 12% and 15%, respectively.

On the other hand, at FAUP, the most reported difficulty among students is "instructor approval" (36%). This issue seems to be directly related to the approach taken in design studios, where students may work on multiple proposals at the same time and rely on the instructor to make the final choice. Other challenges include "design process," "contour line," and "different levels," each occurring at a rate of 21%.

At MIT, the biggest challenge for students is "focus images" (24%). Additionally, "instructor approval" and "lag analysis-design" are also significant challenges, with each occurring at 18%. The latter refers to the difficulty students have in transitioning from an analytical exercise or phase to a synthetic one.

	POLIMI	FAUP	MIT
contour line	2 4%	3 22%	
design process	9 18%	3 22%	2 12%
different levels	3 6%	3 22%	
focus images	8 16%		4 24%
instructor's approval	3 6%	5 36%	3 18%
interpret brief	5 10%		
lack of construction	6 12%		1 6%
lag analysis-design	3 6%		3 18%
total	52 100%	14 100%	17 100%

Table 43. General difficulties of students in the design process

Regarding the challenges faced by students directly related to representation, POLIMI highlights "design moves" (18%) as the most prominent difficulty. This pertains to students' capacity to transform a design through horizontal or vertical movements (Goldschmidt

2014). In addition, a high incidence of difficulties related to the understanding of perspective (13%) and the production of technical representations (13%) is also observed.

At FAUP, the difficulties are markedly distinct in nature. The most reported challenge is related to linking external representations (20%), such as connecting technical drawings such as plans, sections, and elevations, or relating freehand drawings to physical models. Another significant obstacle is the relationship between abstraction and reality in representations (15%).

At MIT, the most significant difficulties include lack of perspective (18%), followed by managing information in representations (18%). A challenge with "lack of perspective" is observed at both POLIMI and MIT, whereas this difficulty is absent at FAUP. This suggests a possible link between this difficulty and the acquisition of freehand drawing skills.

	POLIMI	FAUP	MIT
deal with scale	4 7%	2 10%	3 9%
info management	4 7%	2 10%	5 18%
lack of drawing	6 11%	1 5%	3 9%
lack of perspective	7 13%		6 18%
lag abstract-reality	2 4%	3 15%	3 9%
info management	4 7%	2 10%	4 12%
making models	2 4%	1 5%	2 6%
relate representations	3 5%	4 20%	2 6%
design moves	10 18%	1 5%	4 12%
technical representation	7 13%	2 10%	2 6%
total	56 100%	20 100%	34 100%

Table 44. Representation difficulties of students in design process

4.2.3 Design critiques

This section presents the results on the use of representation during design critiques, which is a crucial component of the design education process. Data pertaining to the employment of representation forms by both instructors and students during critiques were collected and systematically analyzed to identify patterns or trends. This section provides context by describing the general process of design critiques and the background information about the schools studied. It also discusses the modes of interaction between instructors and students, including how instructors provide feedback and how students respond. The section explores how freehand drawing is used during design critiques by both instructors and students, and the impact it has on student learning.

Figure 21. Different layouts for design critiques, POLIMI, 2020

Critiques settings

In this segment, we will analyze the first set of results related to the design critique settings, specifically the modality in which they are conducted in each of the three schools. It is important to note that we are considering regular classes only, and not mid-term or final reviews, nor juries, as these moments follow similar approaches in all three schools.

Our analysis reveals a clear difference among the three schools. At POLIMI, there is a high absolute incidence of group critiques. Conversely, at FAUP, there is a significant incidence of individual critiques (95%). At MIT, we observe a tendency toward individual critiques (65%) but still with a relevant amount of group critiques (35%).

When comparing these data with the exercise modalities (see 4.2.1 Context: Exercises and Briefs), we find a near-perfect correspondence. That is, in design studios where exercises are done individually, critiques are also individual, and in design studios where exercises are done in groups, critiques are also done in groups. These findings highlight the importance of exercise modalities in determining the type of design critique that is most effective (figure 21).

	POLIMI	FAUP	MIT
individual		19 95%	13 65%
group	18 100%	1 5%	7 35%
total	18 100%	20 100%	20 100%

Table 45. Modalities in design critiques

We will now proceed to analyze the type of layout followed in design critiques. We observe that the most frequent in all three cases is the instructor moving around the class from table to table to speak with the students or groups. In this critique layout, design discussions are not directed to the entire class, although in many cases, students gather to hear the critique.

At POLIMI, as previously mentioned, this is the most frequent critique layout (74%), with students or groups also moving to speak with the instructor (16%), and in certain cases, a round table is organized for the entire class. At FAUP, the most frequent layout is also the instructor moving around (83%), followed by the student moving (17%). In no instance were round tables observed in regular critiques during the assisted design studios at FAUP.

At MIT, the situation is different from the other two schools. There is a balanced distribution of different layouts, sometimes varying within the same design studio. The most frequent occurrence is students or groups moving (35%), followed by projected (35%), something that we observe only in the design studios of this institution. Students and

instructors are all connected on their laptops, using platforms such as MIRO, and the critique is displayed on a screen or projection for the entire class. We also observe instructors moving around (30%).

One interesting aspect of the projected design critique dynamic is its similarity to the situation during the pandemic and online teaching. Students share their material on an online platform, and instructors manipulate this material for the entire class to see. It is common in these situations for students to upload both analog representations and digital drawings made on their tablets. While this approach facilitates the sharing and monitoring of the critique by the entire class, we note that interaction with the students' representations is not as efficient as in traditional design critiques.

It should be noted that we are not considering here the rules/restrictions design studios followed during the pandemic at POLIMI and FAUP, as they would affect the results in understanding what design critiques are like outside of an exceptional situation.

	POLIMI	FAUP	MIT
instructor moves	14 74%	5 83%	6 30%
projected			7 35%
round table	2 11%		
student moves	3 16%	1 17%	7 35%
total	19 100%	6 100%	20 100%

Table 46. Different layouts for design critiques

Modes of interaction

In this segment, our focus lies in identifying and categorizing the various modes of interaction utilized by instructors and students during design critiques. We shall begin by examining the modes of interaction employed by instructors, followed by a detailed analysis of the interaction modes used by students. Subsequently, we will undertake a relational examination of these interaction modes between the instructors and students.

Upon scrutinizing the data collected from the three schools, it is noteworthy that the most prevalent modes of interaction utilized by the instructors during design critiques are speech and gestures. Intriguingly, freehand drawing emerges as a significant interaction mode across all three schools. Conversely, model manipulation and transformation occur infrequently across all three schools, and digital manipulation is virtually non-existent except in the case of MIT.

It is pertinent to mention that the present study does not account for adjustments the design studios conducted during the pandemic period, as they are deemed to be an

exceptional circumstance. Nonetheless, during this period, it was observed that digital interaction, which was the sole viable mode, could incorporate a manipulative dimension and thus be efficacious, predominantly through the utilization of digital drawing (see 5.4. Drawing and Online Teaching).

At POLIMI, our analysis reveals that after speech and gestures (43%), freehand drawing follows closely behind (28%), followed by model manipulation (17%). Similarly, at FAUP, it is notable that the occurrence of speech and gestures (43%) is almost equivalent to that of freehand drawing (40%). These results illustrate that in nearly all design studios, instructors use freehand drawing almost as frequently as they communicate through speech or gestures. Finally, at MIT, freehand drawing is also the interaction mode that closely follows speech and gestures (42%), with the lowest incidence rate recorded among the three schools (19%) (figure 22).

	POLIMI	FAUP	MIT
digital manipulation			2 4%
freehand drawing	15 28%	19 40%	9 19%
model manipulation	9 17%	6 13%	6 13%
model transformation	6 11%	2 4%	6 13%
prototype manipulation			5 10%
speech and gestures	23 43%	20 43%	20 42%
total	53 100%	47 100%	48 100%

Table 47. Instructors' modes of interaction in design critiques

In addition, our analysis revealed a consistent choice of interaction modes by students during design studios, albeit with varying rates of incidence. Notably, freehand drawing emerged as the next most common mode of interaction following speech and gestures, although with significantly lower weight than that of instructors.

At POLIMI, the incidence rate of freehand drawing was 19%, following speech and gestures at 53%, with model manipulation and transformation exhibiting equal incidence rates at 14%. At FAUP, despite students receiving formal training in drawing, the incidence of freehand drawing during design critiques was relatively low at 27% compared to a high incidence of speech and gestures at 67%. At MIT, freehand drawing exhibited the lowest incidence rate among the three schools as a mode of interaction at 9%, significantly below speech and gestures at 44%, prototype manipulation at 16%, and even model manipulation and transformation at 13%.

Figure 22. Freehand drawing used for interaction in design critiques, MIT, 2022

	POLIMI	FAUP	MIT
digital manipulation			2 4%
freehand drawing	8 19%	8 27%	4 9%
model manipulation	6 14%	1 3%	6 13%
model transformation	6 14%	1 3%	6 13%
prototype manipulation			7 16%
speech and gestures	23 53%	20 67%	20 44%
total	43 100%	30 100%	45 100%

Table 48. Students' modes of interaction in design critiques

Upon analyzing the two tables, it becomes evident that freehand drawing holds a prominent role in design critiques, particularly on the part of instructors, as it is the most utilized mode of interaction across most design studios. Students also employ this mode of representation to a lesser degree, which is noteworthy, especially for those without prior training in drawing. Conversely, at MIT, freehand drawing is less frequently utilized among students.

These findings are significant in revealing that the use of freehand drawing in the design studio appears to hold greater importance as a mode of interaction between instructors and students than as a tool for students' design processes.

Critiques contents and actions

The content of design critiques delivered by instructors across the three schools will now be the focus of our analysis. We will begin by examining the comments made by instructors during the design critiques, followed by the suggestions made, and within these, those that refer to representation. Finally, we will look at the rate of actions performed by the instructors during the critique, and within these, the type of actions taken.

The first set of results we will examine pertains to the comments made by instructors to students during the design critiques. One notable aspect is the existence of a wide variety of categories, perhaps one of the aspects we have analyzed with the most category proliferation. A general reading of the data indicates that the most frequent focus of comments across all three schools is on the design itself, followed by references to architectural precedents, comments on the representations produced by students, and finally, on the ways of presenting and communicating the design proposal.

Looking at the schools in particular, we can identify some singularities in the proportion of occurrences, as well as some notable themes. At POLIMI, the highest number of occurrences follows the general reading, with a greater number of occurrences related to

design (17%), followed by references to architectural precedents and comments on representation, in equal proportion (15%), and then to comments on the presentation of the proposal.

At FAUP, the situation is quite different, with a much greater incidence of comments made on design (24%), followed by representation and designing principles (13%), then architectural precedents (11%), and finally, comments related to the working process (10%).

At MIT, we see that comments on design are also the most frequent (18%), followed by comments on the working process and ways of presenting and communicating the work, in equal proportion (13%). Comments on educational purposes within the design studio and references to architectural precedents follow in equal proportion (11%). Comments on the constructive aspects of proposals also have some relevance (10%).

	POLIMI	FAUP	MIT
on process	2 3%	8 10%	9 13%
on analysis	5 6%		4 6%
on approaching the site	1 1%	4 5%	2 3%
on construction	1 1%	7 9%	7 10%
on design	13 17%	19 24%	13 19%
on presentation	11 15%	1 1%	9 13%
on representation	12 16%	10 13%	5 8%
on social		1 1%	3 5%
principles of designing	5 6%	10 13%	2 3%
principles of presentation	2 3%		
principles of representation	5 6%	5 6%	1 2%
purposes of teaching	7 9%	5 6%	2 3%
references of architecture	12 16%	9 11%	8 12%
references of general	2 3%	1 1%	5 8%
references of previous		1 1%	1 2%
total	78 100%	80 100%	71 100%

Table 49. Comments made by instructors in design critiques

We will now analyze the suggestions and requests made by instructors to students during design critiques. A general overview of the results reveals that one of the most frequent suggestions across all three schools is for students to produce a new representation. We will delve deeper into this in the following analysis. The second most frequent type of suggestion is for changes to the design, followed by suggestions for improving a particular representation.

At POLIMI, we see that the occurrences match the general trend, with requests for a new representation and suggestions for improving an existing representation tied for first place at the same occurrence rate (21%). This is followed by suggestions for improving the presentation or communication of the proposal (16%), and then suggestions for changes to the design and consulting an architectural precedent, in the same proportion (12%).

At FAUP, the most frequent suggestion is for alternative design ideas (35%), followed by requests to improve an existing representation (26%) and suggestions for alternative work processes (19%).

At MIT, once again, the most frequent suggestion is for a new representation (22%), followed by suggestions for alternative design (17%), and requests to improve an existing representation or to consult an architectural reference, in the same proportion (15%). As with FAUP, we see that suggestions for an alternative work process also have quite a few occurrences (12%).

Overall, it appears that across all three schools, the most common feedback given to students during design critiques is the need for a new representation or alternative ideas for the design proposal. Suggestions for improving existing representations and altering the design are also common. Additionally, recommendations for improving the communication and presentation of the design, as well as suggestions for alternative work processes, also have a significant presence.

	POLIMI	FAUP	MIT
alternative design	7 12%	15 35%	7 17%
alternative process	5 9%	8 19%	5 12%
alternative representation		2 5%	
dynamic representation	3 6%		1 3%
improve the analysis	2 4%		3 8%
improve the presentation	9 16%	2 5%	6 15%
improve the representation	12 21%	11 26%	4 10%
new representation	12 21%	3 7%	9 22%
see a reference	7 12%	1 3%	6 15%
visit the site	2 4%	1 3%	
total	59 100%	43 100%	41 100%

Table 50. Suggestions made by instructors in design critiques

We will now turn our attention toward the requests made by instructors for the creation of new representations in the context of architectural design education. After a thorough analysis of the data collected from the three schools, it is evident that there is a significant

degree of consistency in the requests made by the instructors, although minor variations in proportion exist among the institutions.

The findings indicate that freehand drawings are one of the most frequently requested forms of representation across all three schools. This is in line with the long-standing tradition of freehand drawing as a fundamental tool for the ideation and conceptualization of architectural ideas.

Despite the prevalence of freehand drawings, technical representations and physical models were also requested with notable frequency. These types of representations are essential in conveying technical information and exploring materiality, respectively, which are integral aspects of architectural design. At FAUP, in particular, technical representations were requested more frequently than any other type of representation, highlighting the importance of technical proficiency in architectural education.

	POLIMI	FAUP	MIT
digital model			1 11%
freehand drawing	5 42%	4 31%	2 22%
physical model	3 25%	4 31%	1 11%
prototype			3 33%
render	1 8%		
technical representation	3 25%	5 38%	2 22%
total	12 100%	13 100%	9 100%

Table 51. Requested representations by instructors in design critiques

When analyzing the actions taken by instructors during design critiques, it is important to consider both situations where they take action and situations where they do not. In some cases, instructors may only offer comments and suggestions, while in others, they may actively demonstrate a concept or make changes to the design themselves. After observing design critiques at three different schools, we found that in most cases, instructors did take action. At POLIMI and MIT, values were close to 60%, while at FAUP, it was as high as 95%.

It is worth noting that the high rate of action taken by instructors at FAUP could be due to several factors, such as the specific pedagogical approach used at the school, the expectations placed on instructors, or the level of experience of the students.

	POLIMI	FAUP	MIT
action	15 60%	21 95%	12 57%
no action	10 40%	1 5%	9 43%
total	25 100%	22 100%	21 100%

Table 52. Balance of instructors' actions in design critiques

When analyzing the type of actions taken by instructors during design critiques, we found that the most common action taken by instructors at all three schools is to draw while commenting and making suggestions (figure 23). This type of action was especially prevalent at the observed institutions, suggesting that it is an effective way for instructors to communicate with students during design critiques. The manipulation of physical models was also a common action taken by instructors, indicating that hands-on activities are another effective way to engage with students during the design process. At MIT, we also observed a high occurrence of hybrid analog-digital interactions, which involve the use of both physical and digital tools to manipulate designs. This approach allows instructors to take advantage of the benefits of both types of tools, such as the precision and speed of digital tools and the tactile feedback of physical tools.

	POLIMI	FAUP	MIT
demonstration		2 7%	
drawing record	1 5%		3 13%
hybrid interaction			5 21%
interaction on software		1 3%	1 4%
model manipulation	7 37%	5 17%	5 21%
relate representations		3 10%	
showing drawing	1 5%		1 4%
speech and drawing	10 53%	18 62%	9 38%
total	19 100%	29 100%	24 100%

Table 53. Instructors' types of actions in design critiques

Freehand drawing by instructors

In this segment, we will analyze the use of freehand drawing by instructors in the context of design critiques. We will start by assessing the prevalence of freehand drawing in the design studios of the three schools and then delve deeper into the frequency levels, whether high, medium, or low. We will then consider the various uses of freehand drawing by instructors, the settings in which it is employed, and the media in which it is produced.

Figure 23. Instructor drawing during design critiques, FAUP, 2022

The first set of results pertains to the prevalence of freehand drawing when used by design studio instructors. Upon examining the data from the three schools, we observe that freehand drawing is highly relevant across all of them. At POLIMI, freehand drawing was present in 68% of the observed design studios, at FAUP in 95%, and at MIT in 45%, which, although the lowest rate, remains significant.

	POLIMI	FAUP	MIT
y	15 68%	19 95%	9 45%
n	7 32%	1 5%	11 55%
total	22 100%	20 100%	20 100%

Table 54. Balance of freehand drawing used by instructors in design critiques

We will now examine the frequency of freehand drawing within design studios, classifying its usage into three categories: high, medium, and low frequency. Substantial differences in the usage of freehand drawing are found across the three schools. At POLIMI, high frequency (60%) is the most observed category, followed by medium frequency (33%). At FAUP, high frequency is consistently observed in all design studios. At MIT, a medium frequency of freehand drawing usage is observed in most design studios (89%), with high frequency being less common (11%).

	POLIMI	FAUP	MIT
high	9 60%	19 100%	1 11%
medium	5 33%		8 89%
low	1 7%		
total	15 100%	19 100%	9 100%

Table 55. Frequency of freehand drawing used by instructors in design critiques

Taking into consideration the purpose of freehand drawing utilized by instructors in design critiques, we can observe that the predominant focus across the three schools is on design composition. However, upon closer examination, we can identify nuances in the usage of freehand drawing. At POLIMI, although design composition is a prevalent focus (23%), it is surpassed by the application of freehand drawing to discuss presentation and communication strategies (26%). Moreover, a considerable occurrence rate is observed in the use of freehand drawing for student representations (21%), followed by a focus on constructive aspects (12%).

Figure 24. Instructor's drawing to discuss both composition and construction, FAUP, 2022

At FAUP, the main objective of freehand drawing is discussing design compositions (43%), followed by a focus on constructive aspects (20%), which are directly related to design. Representation (19%) and presentation and communication of proposals (18%) also have considerable occurrence rates. At MIT, design composition is the most prevalent usage of freehand drawing among the three schools (69%), followed by an additional application that is not observed in the other cases, which is the focus on the production of the proposal (31%). This pertains to design objects, installations or sculptures, or furniture pieces.

Hence, we can discern that at POLIMI, freehand drawing is employed in a balanced manner for the purpose of design itself, encompassing composition, construction, representation, and presentation. At FAUP, the primary focus is on both composition and construction (figure 24). At MIT, the usage of freehand drawing is highly concentrated on the compositional dimension of design, as well as production modes, considering the diverse nature of design in this institution.

	POLIMI	FAUP	MIT
analysis	3 3%		
construction	5 12%	9 20%	
composition	10 23%	19 43%	9 69%
presentation	11 26%	8 18%	
production			4 31%
references	2 5%		
representation	9 21%	8 19%	
total	42 100%	44 100%	13 100%

Table 56. Functions of freehand drawing used by instructors in design critiques

In the study of the use of freehand drawing in design critiques, different configurations of freehand drawings used by instructors across the three schools were analyzed. The data showed that across all institutions, there tended to be a balance between the different configurations of freehand drawing, with “scheme” being the most frequent configuration in all three. This suggests that instructors across these schools prioritize using freehand drawings to convey ideas and concepts in a schematic way.

At POLIMI, the most frequent configuration of freehand drawing was the “scheme” (33%), which is a simplified representation of the design that highlights its main features. Technical representations such as plans, sections, and elevations were the second most frequent form of freehand drawing (29%), indicating that instructors at POLIMI also prioritize conveying technical details through freehand drawings. Additionally, freehand

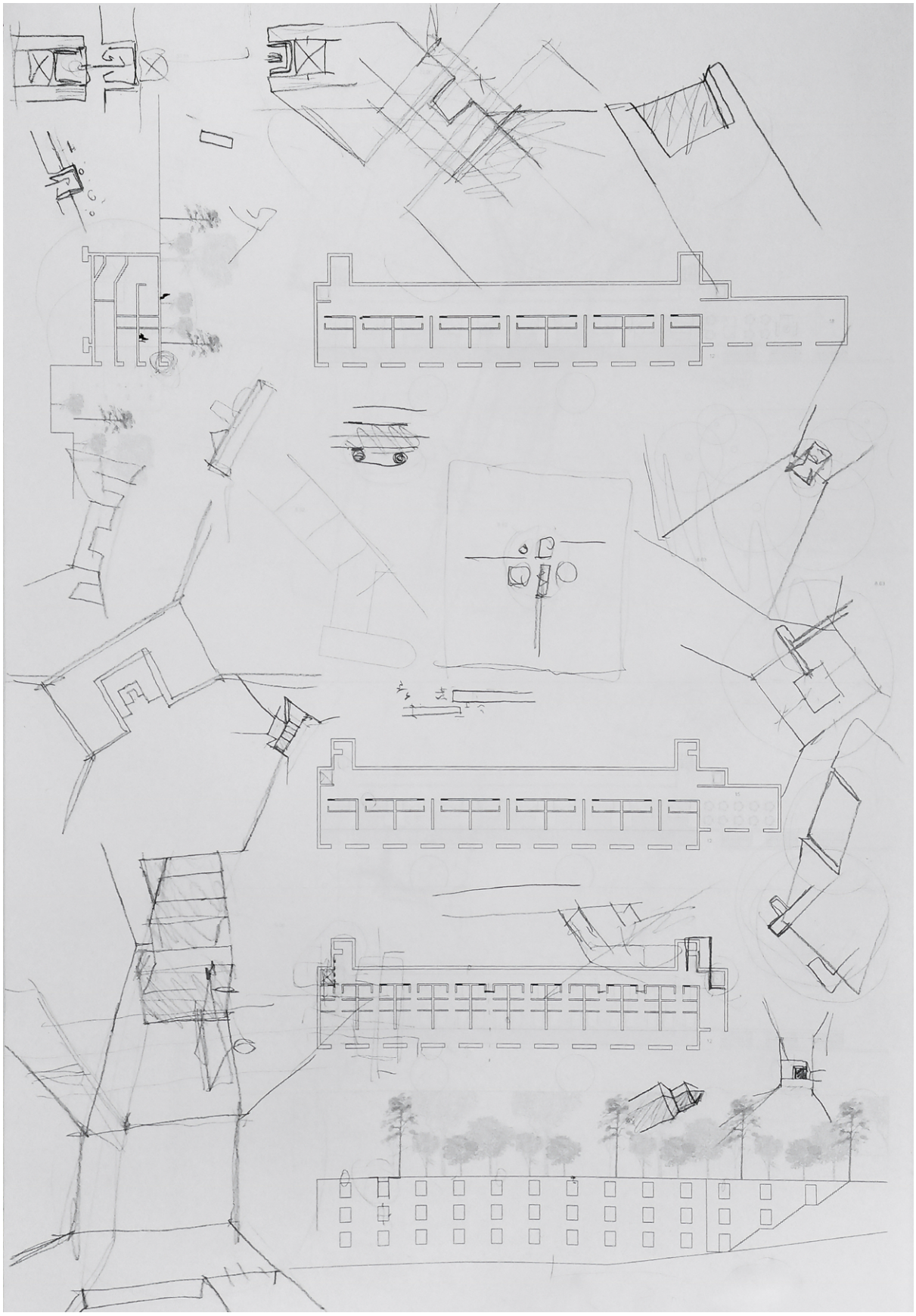


Figure 25. Instructor's annotations on student's work, FAUP, 2021

drawing used as graphical notes held significant relevance (21%), indicating that instructors at POLIMI also use freehand drawings to annotate and clarify their ideas.

At FAUP, the most frequent configurations of freehand drawing were technical representations, perspectives, and graphical notes, each with an equal occurrence rate of 25%. This suggests that instructors at FAUP prioritize using freehand drawings to convey technical details, spatial relationships, and annotations equally. The "scheme" configuration also had high values, indicating that instructors at FAUP also value using freehand drawings to convey schematic ideas.

At MIT, the most frequent configurations of freehand drawing were technical representations, "schemes," and graphical notes, all with equal values (32%). This suggests that instructors at MIT also prioritize using freehand drawings to convey technical details and schematic ideas, with graphical notes being used to annotate and clarify their ideas.

Overall, the data suggests that freehand drawing is an important tool used by instructors in design critiques across these three schools, with "scheme" being the most frequent configuration. However, the data also showed that the use of freehand drawing varied across the schools, with FAUP distinguishing itself as the school that prioritizes using freehand drawings in perspective. Additionally, the data showed that freehand drawing is not considered as an essential tool for all instructors, as many do not use it at all.

	POLIMI	FAUP	MIT
note	9 21%	19 25%	9 32%
perspective	7 17%	19 25%	1 4%
scheme	14 33%	18 24%	9 32%
technical	12 29%	19 25%	9 32%
total	42 100%	75 100%	28 100%

Table 57. Types of freehand drawing used by instructors in design critiques

The data presented in this section focuses on the support where freehand drawing is produced by instructors during design critiques in the three different schools. The data show that the most frequent support across all three schools is drawing directly on students' representations, where instructors provide feedback and suggestions by adding their own drawings and annotations on top of students' work (figure 25).

At POLIMI, the data show that drawing on students' representations is relevant but not as common as drawing on plain paper. Instructors at POLIMI tend to use plain paper as the primary medium for freehand drawing, with 31% of instructors reporting that they use it. Drawing on students' representations is also relevant at POLIMI, with 28% of instructors

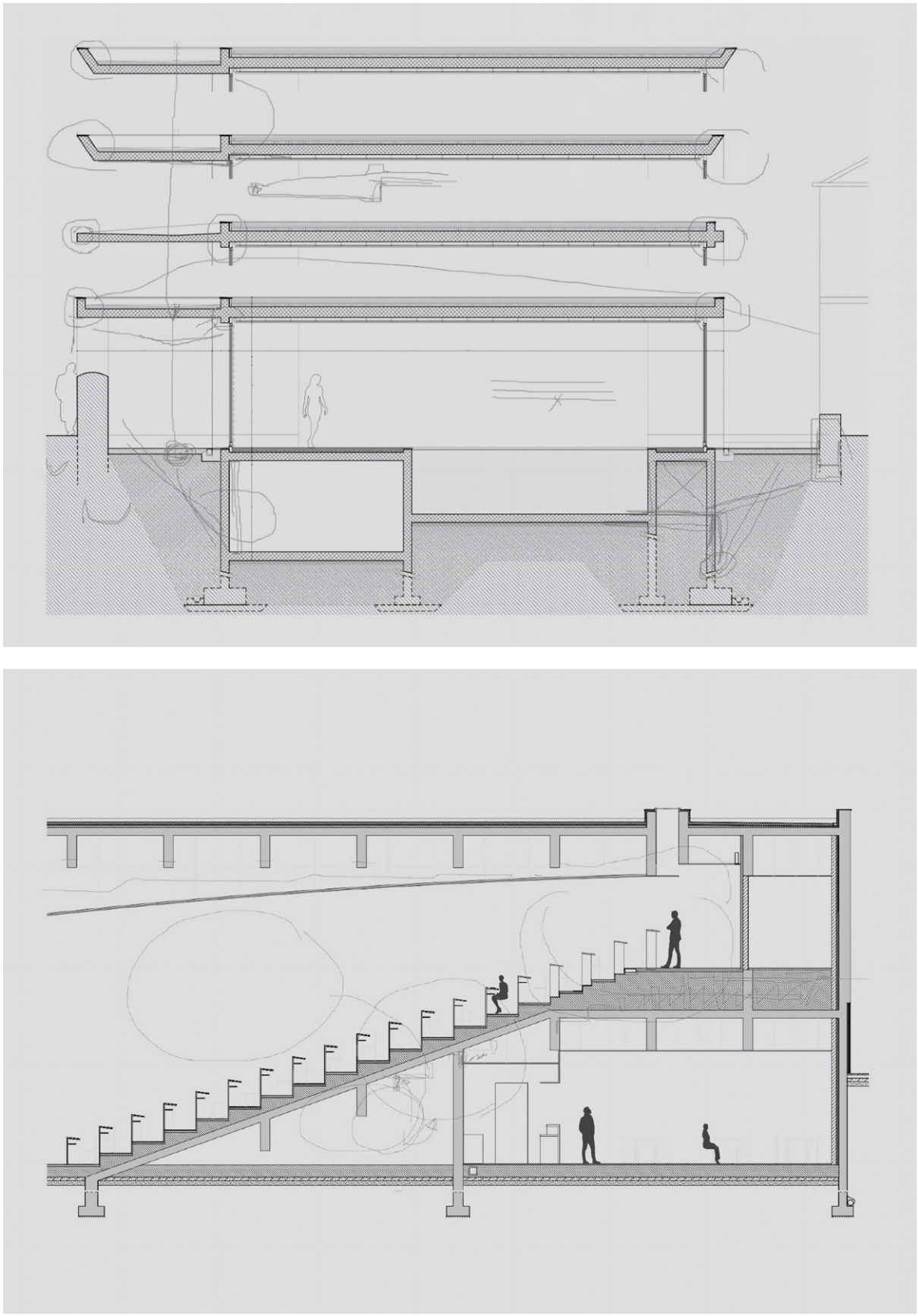


Figure 26. Shared screen: Instructor's annotations on student's work, FAUP, 2021

reporting that they use it. Personal notebooks are also a popular medium for freehand drawing at POLIMI, with 25% of instructors reporting that they use them.

At FAUP, the data reveal that drawing on students' representations is by far the most common medium, with 58% of instructors reporting that they use it. Tracing paper is the next most common medium, with 16% of instructors reporting that they use it. Instructors at FAUP tend to use freehand drawing to provide feedback and suggestions to students directly on their representations, which suggests a focus on collaboration and iterative design processes.

At MIT, the data show that drawing on plain paper is the most common medium for freehand drawing, with 41% of instructors reporting that they use it. Drawing on students' representations is the next most common medium, with 32% of instructors reporting that they use it. Instructors at MIT seem to use freehand drawing to brainstorm and ideate, with plain paper providing a blank canvas for their ideas.

	POLIMI	FAUP	MIT
blackboard		4 13%	
notebook	9 25%		3 14%
plain paper	11 31%	4 13%	9 41%
student rep	10 28%	18 58%	7 32%
tracing paper	6 17%	5 16%	3 14%
total	36 100%	31 100%	22 100%

Table 58. Support types for freehand drawing used by instructors in design critiques

One significant aspect of freehand drawing and other forms of representation utilized in design critiques is their impact on the manipulation of the representations. This quality is closely related to the previous point, which identified the contexts in which instructors employ freehand drawing.

Our observations indicate that when freehand drawing is executed directly on an existing representation, such as the student's drawing or using tracing paper, it assumes a manipulative function (figure 26). Conversely, when freehand drawing is performed on a blank sheet of paper, personal notebook, or blackboard (figure 27), it lacks manipulative capabilities. Notably, our observations reveal a slight prevalence of non-manipulative freehand drawing at both POLIMI and MIT, where the distribution is otherwise equitable. Manipulative freehand drawing accounts for 44% at POLIMI and 45% at MIT. Conversely, our data demonstrate a marked prevalence of manipulative freehand drawing (74%) at FAUP.

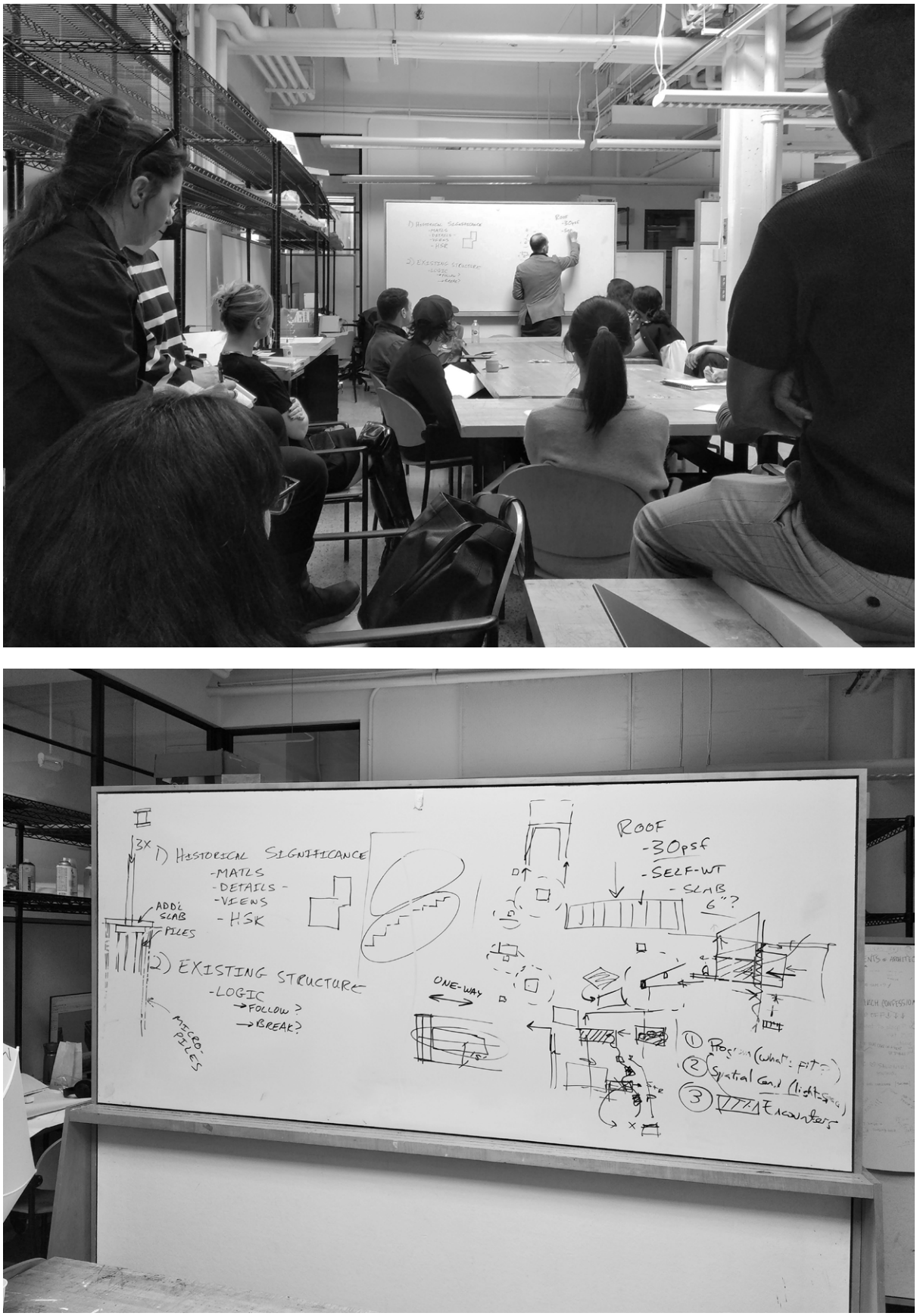


Figure 27. Instructor drawing on a blackboard, MIT, 2022

	POLIMI	FAUP	MIT
manipulative	16 44%	23 74%	10 45%
non-manipulative	20 56%	8 26%	12 55%
total	36 100%	31 100%	22 100%

Table 59. Manipulation balance of freehand drawing used by instructors in design critiques

Freehand drawing by students

After analyzing the use of freehand drawing by instructors in design critiques, we will now investigate its prevalence and patterns of use by students. To this end, we conducted a systematic examination of the use of freehand drawing in the design studios of three schools, with a focus on determining the frequency and nature of its use. To begin, we conducted a thorough assessment of the presence of freehand drawing in design critiques across the three schools. Our findings indicate that, unlike with instructors, the use of freehand drawing among students is not uniformly high across all three cases.

At POLIMI, freehand drawing is observed in a balanced distribution, appearing in 41% of the observed situations. At FAUP, we found the highest incidence of freehand drawing in all three cases, with a presence of 72% in design critiques. In contrast, freehand drawing was observed least frequently at MIT, with a rate of only 26%.

Moreover, we also analyzed the circumstances in which freehand drawing was utilized by students, examining whether it was requested by instructors or arose spontaneously. This information is crucial to understanding the contexts in which students employ freehand drawing in their design work. Additionally, we examined the ways in which students utilize freehand drawing, the settings in which it is employed, and the media in which it is produced.

	POLIMI	FAUP	MIT
y	9 41%	13 72%	5 26%
n	13 59%	5 28%	14 74%
total	22 100%	18 100%	19 100%

Table 60. Balance of freehand drawing used by students in design critiques

When considering the level of frequency of freehand drawing across the three schools, it is evident that there is significant variability in the distribution of occurrences. At POLIMI, a higher diversity of frequency levels was observed, with the most prominent being the medium level (56%), followed by the low level (33%), which remains of considerable relevance. FAUP, on the other hand, predominantly showed a high level (77%), followed by a

low level (15%) that was of minimal significance. Finally, at MIT, the data indicate that in all design critiques examined, the frequency level of freehand drawing was consistently medium.

	POLIMI	FAUP	MIT
high	1 11%	10 77%	
medium	5 56%	1 8%	5 100%
low	3 33%	2 15%	
total	9 100%	13 100%	5 100%

Table 61. Frequency of freehand drawing used by students in design critiques

The analyzed data pertain to the rate of freehand drawing in design critiques among students, and we are interested in determining the frequency of spontaneous use, use when requested by instructors, and situations where both occur in the same design studio. However, the situation differs across the three schools under review.

At POLIMI, most observed situations point to a mixed scenario where freehand drawing is both requested by instructors and occurs spontaneously, with a frequency of 56%. Situations where freehand drawing occurs spontaneously are also relevant, accounting for 33% of the observations. At FAUP, the most frequent occurrence is the spontaneous use of freehand drawing by students, accounting for 54% of the observations. In contrast, situations where instructors requested the use of freehand drawing accounted for 46% of the observations, making it almost symmetrical to spontaneous use. At MIT, the findings indicate that the use of freehand drawing in design critiques arises spontaneously in students, and there were no instances where instructors requested the use of freehand drawing.

	POLIMI	FAUP	MIT
demanded	1 11%	6 46%	
spontaneously	3 33%	7 54%	5 100%
both	5 56%		
total	9 100%	13 100%	5 100%

Table 62. Rate of demanded-spontaneous freehand drawing used by students in design critiques

In this analysis, we will examine the functions that students are assigned during design critiques. We observed a similar trend to that of the instructors, where design composition

was the most frequent function across all three schools. However, some categories, such as the constructive dimension of design, were not present in this analysis.

At POLIMI, most freehand drawings used by students during design critiques were for design composition (47%) (figure 28), followed by analysis (33%) and presentation and communication (20%), which also had a significant presence. At FAUP, all freehand drawings used by students during design critiques were for design composition. At MIT, design composition was the most relevant function (50%), followed by production (30%), which is a unique feature of this institution, similar to the trend observed in instructors. Additionally, the analysis function also had notable relevance (20%).

	POLIMI	FAUP	MIT
analysis	5 33%		2 20%
composition	7 47%	13 100%	5 50%
presentation	3 20%		
production			3 30%
total	15 100%	13 100%	10 100%

Table 63. Functions of freehand drawing used by students in design critiques

Shifting our focus to the different configurations that freehand drawing utilized by students during design critiques, it becomes apparent that technical representations hold the highest prevalence in all three cases, followed by graphical notes. Notably, similar to those found with instructors, some distinctive features are observable among the three institutions.

At POLIMI, technical representations represent the most frequently used configuration at 45%, followed by “scheme” at 30%, and graphical notes at 25%. Conversely, at FAUP, graphical notes manifest as the most prevalent configuration at 35%, followed by perspective and technical representations, with an equal incidence of 30%. It is noteworthy that the employment of perspective appears to be predominantly exclusive to this institution. Lastly, at MIT, graphical notes and technical representations (figure 29) demonstrate an equal frequency of occurrence at 36%, followed by “scheme” at 29%.

	POLIMI	FAUP	MIT
note	5 25%	13 35%	5 36%
perspective		11 30%	
scheme	6 30%	2 5%	4 29%
technical	9 45%	11 30%	5 36%
total	20 100%	37 100%	14 100%

Table 64. Types of freehand drawing used by students in design critiques

Figure 28. Student's annotations on her own work, POLIMI, 2021

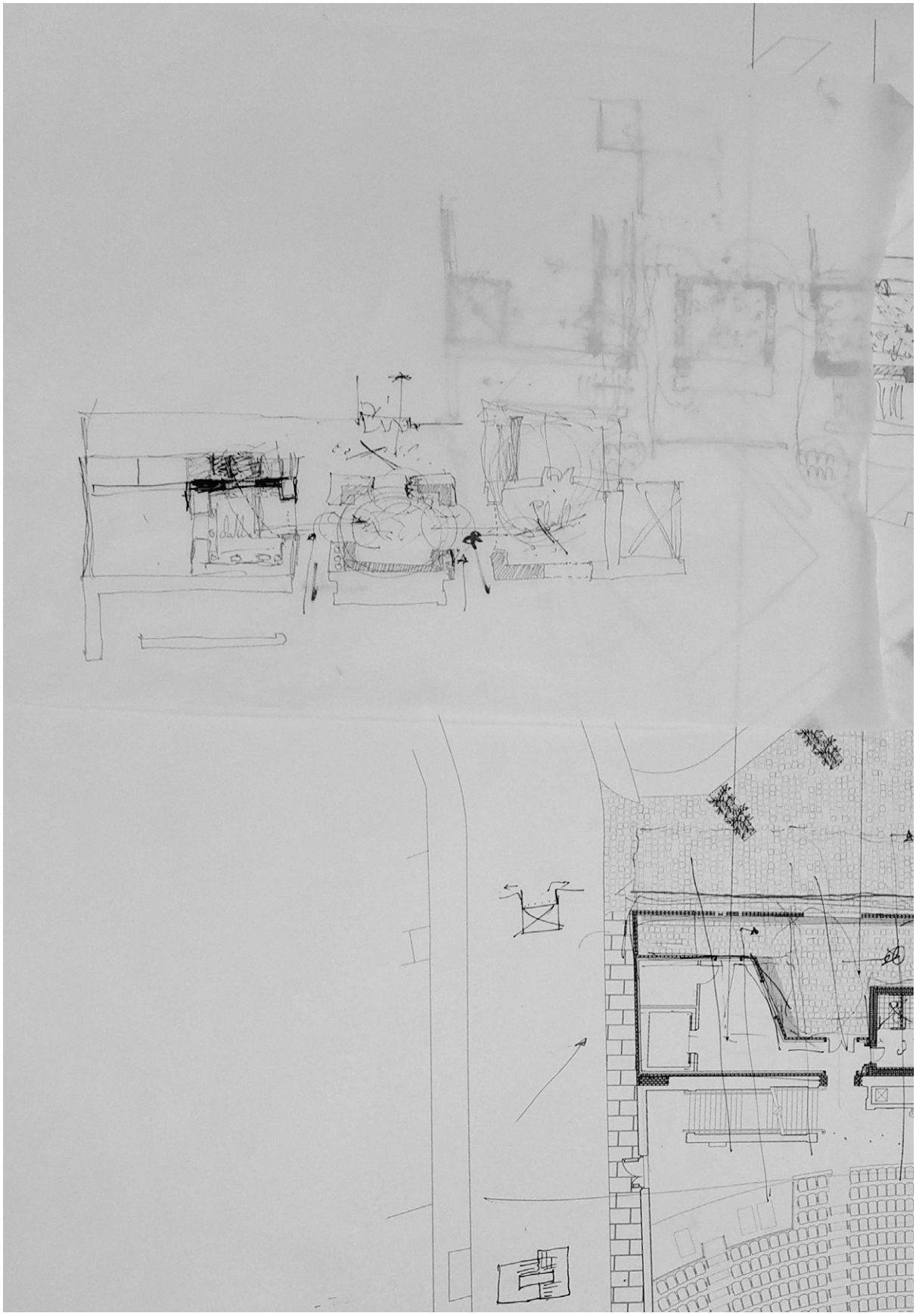


Figure 29. Student's technical representations on tracing paper, MIT, 2022

Figure 30. Student's drawings on tracing paper, FAUP, 2022

In the following, we will analyze the support used by students for freehand drawing. Our observations show that in all three institutions, the most prevalent support is the students' own representations, regardless of whether they are hand-drawn or printed from digital drawings. At POLIMI, the incidence of student representations is equivalent to plain paper at 50%. At FAUP, in addition to student representations (54%), we have noticed that students frequently employ tracing paper (25%) (figure 30) and, only subsequently, plain paper (20%) (figure 31). This finding highlights the importance of tracing paper as a tool in design education.

On the other hand, the use of tablets at MIT has exhibited a diverse distribution, with freehand drawings made on tablets showing the highest incidence at 33%, followed by student representations, plain paper, personal notebooks, and tracing paper, all exhibiting an equal incidence of 20%. Interestingly, the use of tablets as a substitute for personal notebooks at MIT also provides the possibility of overlaying images and representations. As a result, in some cases, students utilizing the tablet may be drawing on top of their own previous work, such as a CAD drawing, indicating the integration of digital and traditional media in design education.

	POLIMI	FAUP	MIT
notebook	5 31%		1 7%
plain paper	8 50%	5 21%	2 13%
self-representations	3 19%	13 54%	4 27%
tablet			5 33%
tracing paper		6 25%	3 20%
total	16 100%	24 100%	15 100%

Table 65. Support types for freehand drawing used by students in design critiques

As previously observed in the case of instructors, a notable characteristic of freehand drawing during design critiques is its potential for manipulation. The tablet utilized as a medium of support may be employed to manipulate pre-existing representations or to create entirely new ones, thus warranting its inclusion within the manipulative category.

Upon evaluating the results, it becomes evident that the employment of freehand drawing as a manipulative tool is prevalent across all three institutions, albeit to varying degrees. At POLIMI, manipulative freehand drawing accounts for 50% of its use. At FAUP, it is noteworthy that the most recurrent application of freehand drawing is manipulative (79%). Finally, at MIT, although the distribution is less pronounced, a notable preponderance of manipulative freehand drawing (60%) is still observed.

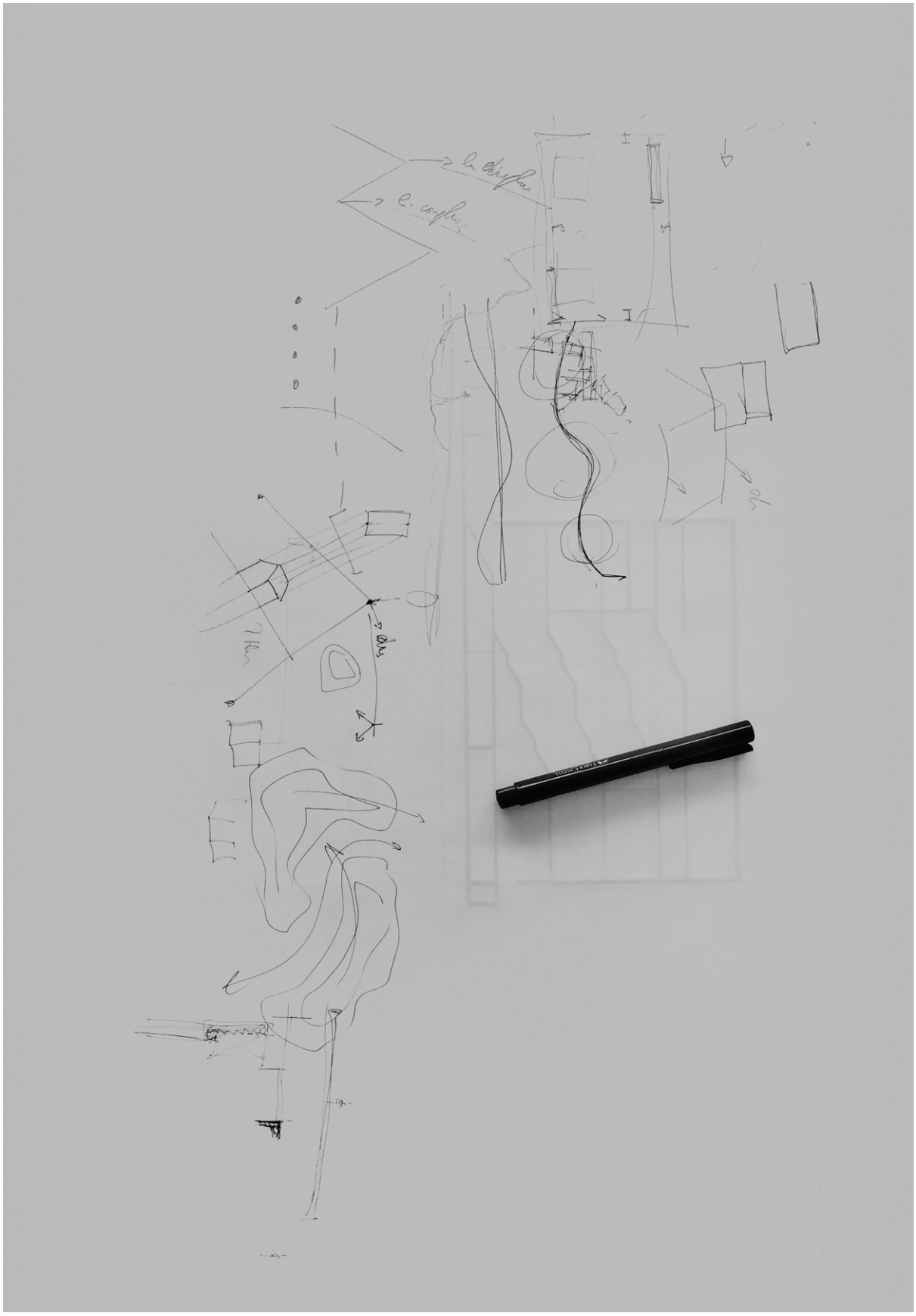


Figure 31. Student's drawing using the back of a CAD representation, FAUP, 2021

	POLIMI	FAUP	MIT
manipulative	8 50%	19 79%	9 60%
non-manipulative	8 50%	5 21%	6 40%
total	16 100%	24 100%	15 100%

Table 66. Manipulation balance of freehand drawing used by students in design critiques

4.3 Synthesis

In the final part of this chapter, we will provide a summary of the data highlighted in the previous section. All categories will be referenced, but only the most frequent or relevant data will be mentioned. Data will not be interpreted at this stage. In the discussion chapter, these data will be revisited, and their significance for the conclusions of this research will be discussed (see 6.2. The Relevance of Freehand Drawing).

4.3.1 Context

Class settings

Regarding the number of instructors in design classes, at POLIMI, most design studios have 2 instructors (56%). In contrast, at FAUP and MIT, most design studios have only 1 instructor (95% and 81%).

Considering the number of teaching assistants in design classes, we observe that none of the studios at FAUP have assistants, while at POLIMI and MIT, there are assistants in almost all studios (96% and 81%). The number of assistants varies in these two schools, with POLIMI showing more diversity, ranging from 1 to 8 assistants.

Regarding the presence of guest speakers in design studios, it is rarely practiced at FAUP. In contrast, at POLIMI and MIT, guests are present in nearly half of the attended design studios (48% and 50%).

Exercises and briefs

Considering the nature of the design exercises, we observe variations among the three schools. At POLIMI, most exercises are of mixed nature (68%), but with some specific characteristics related to analytical exercises. At FAUP, almost all exercises have a synthetic nature (95%), while at MIT, they are divided between mixed (52%) and synthesis exercises (43%).

Within synthetic exercises, there is a prevalence of exercises with a real, visitable, and nearby context in all three schools. MIT stands out by having a high incidence of real but non-visitable contexts (30%).

Modalities

Regarding the modalities followed in design exercises, at POLIMI, group work represents the overwhelming majority (92%), unlike FAUP, where the majority are individual exercises (95%). MIT shows a more balanced distribution, with a prevalence of individual exercises (67%). Concerning the number of students per group, POLIMI exhibits greater diversity, with groups of 4 students being prevalent (46%), while at MIT, all groups consist of 2 students (100%).

4.3.2 Design process

External representations

Considering the types of representation media used by students in the design process, both at POLIMI and MIT, there is a prevalence of mixed media, combining analog and digital methods (87% and 85%), while at FAUP, analog media hold greater relevance (67%).

Regarding the most frequently used support types by students, at POLIMI, there is an equivalence between digital support and plain paper (33%). At FAUP, paper-based supports like notebooks, plain paper, and tracing paper are most common, all with the same frequency (27%). In contrast, at MIT, digital support is the most frequent (33%).

Regarding the most frequently used forms of representation by students in the three schools, at POLIMI and MIT, there is a wide variety, with technical representations prevailing (20% and 16%). FAUP stands out for its high incidence of freehand drawing (42%).

An important aspect of our analysis is the assessment of the dynamic or static nature of representations. In this regard, POLIMI exhibits a prevalence of static representations (61%), FAUP has dynamic representations as the majority (50%), and MIT features a mix of both (75%).

Technical representations

When considering the styles of technical representations used by students, we observe differences among the three schools. At POLIMI and MIT, stylized representations are the

most frequent (41% and 48%), while at FAUP, clear preferences lean toward technical representations (76%).

Regarding the diversity of technical representation styles within the same design studio, most students at POLIMI use multiple styles (72%). FAUP tends to use a single style (75%), while MIT shows a balanced distribution between single and multiple styles.

Physical models and prototypes

Analyzing the presence of physical models and prototypes in students' processes, their importance is evident in all three schools, particularly at POLIMI and FAUP (84% and 86%). The frequency is also high at MIT (43%), with prototypes being used exclusively at MIT (38%).

In all three schools, most of these models and prototypes are handmade, primarily using cardboard and Styrofoam. Cardboard is the preference at POLIMI (67%), while Styrofoam is more common at FAUP (61%). MIT exhibits a greater material variety, including acrylic, metal, and wood.

Considering the style of physical models, the abstract style prevails at both POLIMI and FAUP (61% and 100%), while MIT has a split between abstract and thematic styles.

Returning to the assessment of the dynamic or static nature of students' productions, it is observed that models in both POLIMI and MIT are mostly static (90% and 100%), while FAUP leans toward dynamic productions (47%).

Freehand drawing

When considering the presence of freehand drawing in students' design processes, all three schools highly value freehand drawing, with values exceeding 80%. FAUP stands out, particularly in the first two years, when freehand drawing is mandatory.

This becomes clearer when analyzing the frequency of freehand drawing. It is less frequent at POLIMI (75%), high at FAUP (53%), and average at MIT (76%).

The functions for which freehand drawing is employed vary. At POLIMI, it is primarily used for communication (64%); at FAUP, as a design tool (29%), followed closely by observation and analysis (each at 24%); and at MIT, drawing is mainly used as a design tool (48%), followed by presentation (39%).

Considering the types of drawings created by students, there are differences between the three schools. At POLIMI, technical representations and diagrams are the most common (32%). Similarly, at MIT, diagrams are the most frequently used type of drawing (35%),

followed by technical representations (31%). In contrast, at FAUP, perspectives are more relevant (42%).

Finally, regarding the types of media used by students, differences exist among the three schools. Plain paper is most used at POLIMI (57%), as it is at FAUP (40%), although tracing paper holds special relevance at the latter (30%). At MIT, plain paper and notebooks are the most used (33%), but digital drawing is also notably relevant (29%).

Students' difficulties

Regarding the general difficulties reported by students, at POLIMI, the most relevant difficulty is related to the design process (18%). At FAUP, there is a high need for instructor approval (36%), while at MIT, an excessive focus on images is noted (24%).

When analyzing difficulties directly related to representation, it is observed that at POLIMI, students struggle with "design moves" (18%). Furthermore, both at POLIMI and MIT, there is a challenge associated with understanding and representing perspective. At FAUP, difficulties include relating different external representations (20%) and connecting abstraction to the reality of a representation (15%).

4.3.3 Design critiques

Critiques settings

Considering the critique modalities, at POLIMI, they are always conducted in a group format, largely due to the group nature of the exercises. In contrast, at FAUP, the majority are individual modalities (95%). MIT shows a more balanced distribution, with the individual modality prevailing (65%).

Regarding critique dynamics, the most common in both POLIMI and FAUP is the instructor moving (74% and 83%). At MIT, there is a greater variety of dynamics, with students moving and projected critiques being the most frequent (both at 35%).

Modes of interaction

Considering the modes of interaction used by instructors during design critiques, freehand drawing is the most frequently used form of representation in all three schools, closely following speech and gestures. Among the three, FAUP records the highest frequency rate (40%), followed by POLIMI (28%) and MIT (19%).

Concerning the modes of interaction employed by students during design critiques, intriguingly, freehand drawing remains highly relevant, although with lower rates, emerging as the primary form of representation. FAUP exhibits the highest frequency (27%), followed by POLIMI (19%) and MIT (9%).

Critiques contents and actions

Taking into account the content of instructors' critiques during design sessions, the most frequent focus in all three schools is on design. At POLIMI, design-related comments (17%) are followed by references to precedents and comments on representation in equal proportions (15%). At FAUP, design comments have a higher incidence (24%), followed by comments on representation and design principles (13%). At MIT, design comments (18%) are followed by comments on the working process and ways to present the work (13%).

Considering suggestions and requests, the most frequent one is for students to produce a new representation. At POLIMI, the request for a new representation and improving an existing one have the same frequency (20%). At FAUP, the request for a new representation (25%) is slightly below the suggestion for an alternative design idea (28%). At MIT, the most frequent suggestion is for a new representation (22%), followed by an alternative design idea (17%).

Regarding the type of new representations requested by instructors, freehand drawing is the most common in all three schools, followed by technical representations. At POLIMI, the rate of requesting freehand drawing is the highest of the three (42%), followed by FAUP (31%) and MIT (22%).

Actions taken by instructors during design critiques are observed in most situations. FAUP has the most significant rate (95%), followed by POLIMI (60%) and MIT (57%). The most frequently performed action is speech and drawing, using drawing to accompany comments. FAUP has the highest rate (62%), followed by POLIMI (53%) and MIT (38%).

Freehand drawing by instructors

Considering freehand drawing used by instructors during design critiques, its presence is significant in all three schools, starting with FAUP (95%), followed by POLIMI (68%), and MIT (45%). When considering the frequency, there is a high frequency at FAUP (100%) and POLIMI (60%) and a medium frequency at MIT (89%).

Regarding the functions attributed to drawings by instructors, at POLIMI, the most frequent function is discussing presentation and communication strategies (26%), followed by design composition (23%). At FAUP, the majority relates to design composition (43%),

followed by constructive aspects (20%). At MIT, design composition is also the most relevant (69%), followed by the proposal's production method (31%).

The most common types of freehand drawing at POLIMI are schemes (33%), followed by technical representations (29%). At FAUP, technical representations, perspectives, and graphical notes all have the same frequency (25%). At MIT, technical representations, schemes, and graphical notes all have the same frequency (32%).

Regarding the media for freehand drawing, plain paper is the most frequent at POLIMI and MIT (31%), while at FAUP, the students' own representations are used (58%). This is related to the manipulative nature of drawing, with POLIMI and MIT being mostly non-manipulative (56% and 55%), while manipulative drawing prevails at FAUP (74%).

Freehand drawing by students

Finally, considering the use of freehand drawing by students during design critiques, we observe a significant prevalence at FAUP (72%). In the other two schools, even though most students do not resort to freehand drawing during critiques, it remains relevant, starting with POLIMI (41%) and then MIT (26%). Within this, the frequency rate of freehand drawing is mostly high at FAUP (77%), while at POLIMI and MIT, it is medium (56% and 100%).

Here, we consider the balance between spontaneous or requested freehand drawing and realize that it is mostly mixed at POLIMI (56%), while at FAUP and MIT, it is spontaneous (54% and 100%).

Regarding the functions attributed to freehand drawing, at POLIMI, design composition is the most frequent (47%), followed by analysis (33%). At FAUP, design composition is the sole function (100%). At MIT, design composition also prevails (50%), followed by production (30%).

Concerning the types of freehand drawings produced by students, at POLIMI, technical representations are the most common (45%). At FAUP, graphical notes are the most frequent (35%), followed by perspective and technical representations in equal proportions (30%). At MIT, graphical notes and technical representations have equal incidence (36%).

When considering the media used, plain paper is the most common at POLIMI (50%). At FAUP, student representations are the most frequent (54%), with notable use of tracing paper (25%). At MIT, the tablet is the most used medium (33%).

Finally, regarding the manipulative or non-manipulative use of freehand drawing, in all three schools, drawing is predominantly manipulative, with FAUP having the highest incidence (79%), followed by MIT (60%) and POLIMI (50%).

Chapter 5 Complementary readings

5.1 Presentation

In this chapter, we will present a set of complementary studies to the results presented previously. They were developed simultaneously with the data collection of the design studios in the three schools, as informative and supplementary topics or nuances directly related to our research questions. As we will see, methodologically the first three sections are in line with the general procedures used for data collection and analysis, with a substantial difference in the fourth and final section, based on archival research.

In the first section, *Drawing and Perception*, we provide an in-depth overview of the teaching and learning of drawing at FAUP, focusing on two drawing courses. The section not only outlines the key assumptions that underpin the teaching of drawing but also contextualizes the two courses within the Master's program in Architecture. Moreover, the section further discusses the practical and theoretical aspects of both courses, highlighting the roles of instructors and students in the learning process. Overall, this section provides a comprehensive picture of the teaching and learning of freehand drawing at FAUP, outlining the key elements that contribute to students' mastery of this critical skill. The outcomes of this section were published as a journal paper (Sousa Santos et al 2021d).

In the second section, *Drawing and Design*, the focus shifts to the relationship between drawing courses and design studios at FAUP. The section begins by examining the curricular organization of the program, highlighting the coordination between the courses and the pedagogical approach employed. More specifically, the section sheds light on the prominent role that freehand drawing plays in the first two years of the Master's program, and the effects that it has in the following years. Through an analysis of the intersection between drawing courses and design studios, we will discuss the significance of freehand drawing as a means for design, but also as a didactic tool, fostering interaction between instructors and students in the design studio. The outcomes of this section were published as a conference paper (Sousa Santos et al 2022).

In the third section, *Drawing and Online Teaching*, we examine the impact of online teaching resulting from the Covid-19 pandemic on the design studios of both FAUP and POLIMI, considering the moments of design critiques and freehand drawing. The section analyzes the various teaching modalities that were implemented during the pandemic, including non-presential and mixed modalities, and investigates how design critiques formats evolved, supported largely by digital drawing. By exploring the strengths and weaknesses of

different teaching modalities, we will consider the obstacles that instructors and students encountered in the aftermath of the pandemic and the didactic strategies that were used to surmount them. This section's findings were also published as a conference paper (Sousa Santos et al., 2021c).

Lastly, in the fourth section, *Drawing as a Historical Record*, a set of thesis drawings produced by former MIT students between 1873 and 1968, and archived in this institution as pedagogical material, are analyzed. The goal of this section is to recognize how the significance of drawing has evolved over time, and to do this, the thesis drawings are compared with the course catalogs of the corresponding year. The interpretation of this material allow us to determine the process of transforming the course of architecture at MIT, especially regarding the relationship between forms of representation and the teaching model, and the distinct roles that drawing has assumed over time. The outcomes of this section were published as a journal paper (Sousa Santos et al *in press*).

5.2 Drawing and perception

5.2.1 Outline

This section provides an overview of the teaching and learning of drawing at FAUP, with a specific focus on the *Desenho* 1 and *Desenho* 2 courses in the Integrated Master Program in Architecture. The section outlines the assumptions that underpin the teaching of drawing, emphasizing the importance of continuous practice and the active engagement of students in their own learning. Additionally, the section contextualizes the two courses, with *Desenho* 1 prioritizing the development of both instrumental and expressive components of drawing, while *Desenho* 2 focuses on the intersection between drawing and architectural design. The section further discusses the practical and theoretical aspects of both courses, highlighting the roles of instructors and students in the learning process. Overall, this section provides a comprehensive overview of the teaching and learning of drawing at FAUP. The observation period covered both in-person and online teaching, taking place between November 2020 and March 2021.

5.2.2 Findings

Assumptions in drawing teaching

According to Carneiro (1995), the only way to learn how to draw is by drawing. As in architectural design, the main assumption in the teaching of drawing at FAUP is the need for continued practice, where the role of students as active agents is decisive. The students "learn about their own products and through the perception and interpretation of the work

of others" (Vieira 1995), thus developing their creative and imitative capacities. In this teaching model, students are the "facilitators of their own learning" (Carneiro 1995), asserting themselves as a subject, and not an object, of teaching (Alves Costa 1991).

The instructor, as mentioned by Vieira (in Pais 2018), teaches drawing "indicating paths that can and should be taken, persuading the students to explore them". When approaching the drawing processes, students must be pedagogically followed, "in a continuous process of hypothesis and correction" (Lopes 2017), so that the practice of drawing acquires disciplinary awareness and does not result from pure self-taught. In line with this idea, Cabau (2016) states that the instructor's role is not to "teach how to draw", but rather to provide students with the means and strategies that allow them to "learn how to draw".

There are two complementary dimensions to consider in the teaching and learning of drawing, which, as Caneiro (1995) argues, cannot be separated: the first has to do with instrumental transmissions and acquisitions, that is, with technical representation skills; the second, with the methodological transmissions and acquisitions, which include the procedures of perception, analysis, conception, and communication. Thus, drawing is understood at FAUP not only as a skill, but as an instrument of thought (Barbosa 2018), whose main purpose is the design process (Carneiro in Pais 2018).

Two drawing courses

In this segment we will consider the two drawing courses of the Integrated Master Program in Architecture at FAUP: *Desenho 1* and *Desenho* 2. Both courses are annual, as are all courses in architectural design. The course of *Desenho 1* is taught in the first year of the Master's program and is mainly dedicated to the representation and knowledge of the visible world, not having a direct relationship with the architectural design course of the same year. In general terms, *Desenho 1* aims to systematize the instrumental and expressive component of drawing, giving students the necessary skill and knowledge to represent, with the purpose of developing observation and recording abilities (FAUP 2021a).

The course of *Desenho* 2 is taught in the second year of the Master's program and considers the intersections between drawing and design—and is therefore related to the architectural design course of the same year. In *Desenho* 2, the practice of drawing continues to be developed, consolidating the student's mastery in the use of different representation systems, techniques, codes, and modes of drawing, to grant them autonomy in choosing and constructing an individualized work method. Focusing on the contents of the architectural design course of that year, *Desenho* 2 develops the students' abilities of analysis, conception, and communication (FAUP 2021b).

Figure 32. Different class settings, FAUP, 2016-2017

There are two particularities to consider in the teaching of drawing at FAUP. The first is related to instructors' training: at FAUP, all instructors of drawing have a background in Fine Arts, whether in painting or sculpture. The second is related to the organization of the general curricular plan: during the first two years of the Master's program, students are not allowed to use the computer in architectural design courses. In this way, they are led to work by hand during the first two years, either through drawing or physical models.

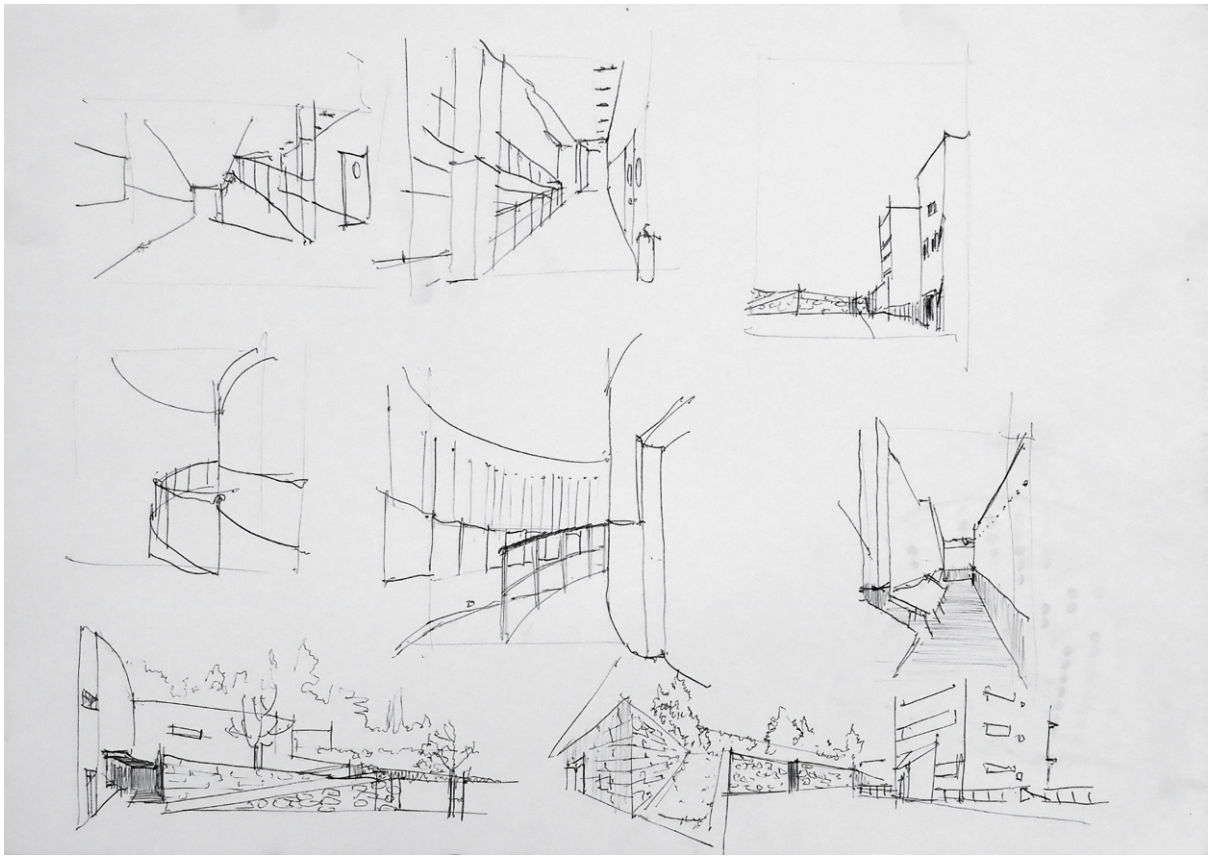
Classes organization

As in architectural design courses, the teaching of freehand drawing is based on practical classes. Classes are made up of around thirty students. While there is a general program for the *Desenho* 1 and *Desenho* 2 courses, instructors have the flexibility to make adjustments based on the specific needs of their class. Classes, which can cover various themes or exercises, may be conducted in the classroom or in alternative indoor or outdoor settings (figure 32). The classes are intense and last four hours in the first year, and three hours in the second.

Each practical class is developed according to a theme. In *Desenho 1*, the themes of the human body, the object, the internal space, and the landscape are addressed (FAUP 2021a). *Desenho* 2, together with the work developed during architectural design, starts with the analysis of visible reality, moving to the study of drawings by reference authors, the conception drawing, and the communication drawing (FAUP 2021b). Throughout both courses, students engage with diverse representation systems, including perspectives with one or two vanishing points—be they linear or atmospheric—, aerial perspectives, axonometric perspectives, and orthogonal projections encompassing plans, sections, and elevations. Additionally, students are tasked with employing various types or modes of drawing, such as contour, sketch, draft, and detail.

The practical class model is similar in both courses. At the beginning of the class, the instructor presents the theme, how the class will be organized, and which exercises will be requested—defining a time per exercise, representative system to follow, the mode of drawing, the sheet format, and the material to be used. Figure 33 shows an example of an exercise: the instructor asked the students to prepare an A3 format sheet with eight sketches in thirty minutes, using perspective with two vanishing points of both interior and exterior spaces. During the elaboration of the exercises, the instructor follows the work of each student, criticizing the positive aspects, pointing out weaknesses, and suggesting how they should continue the drawing.

Practical classes are complemented with theoretical classes. Theoretical classes cover topics such as light and dark, compositional aspects, the use of color, expression and framing,



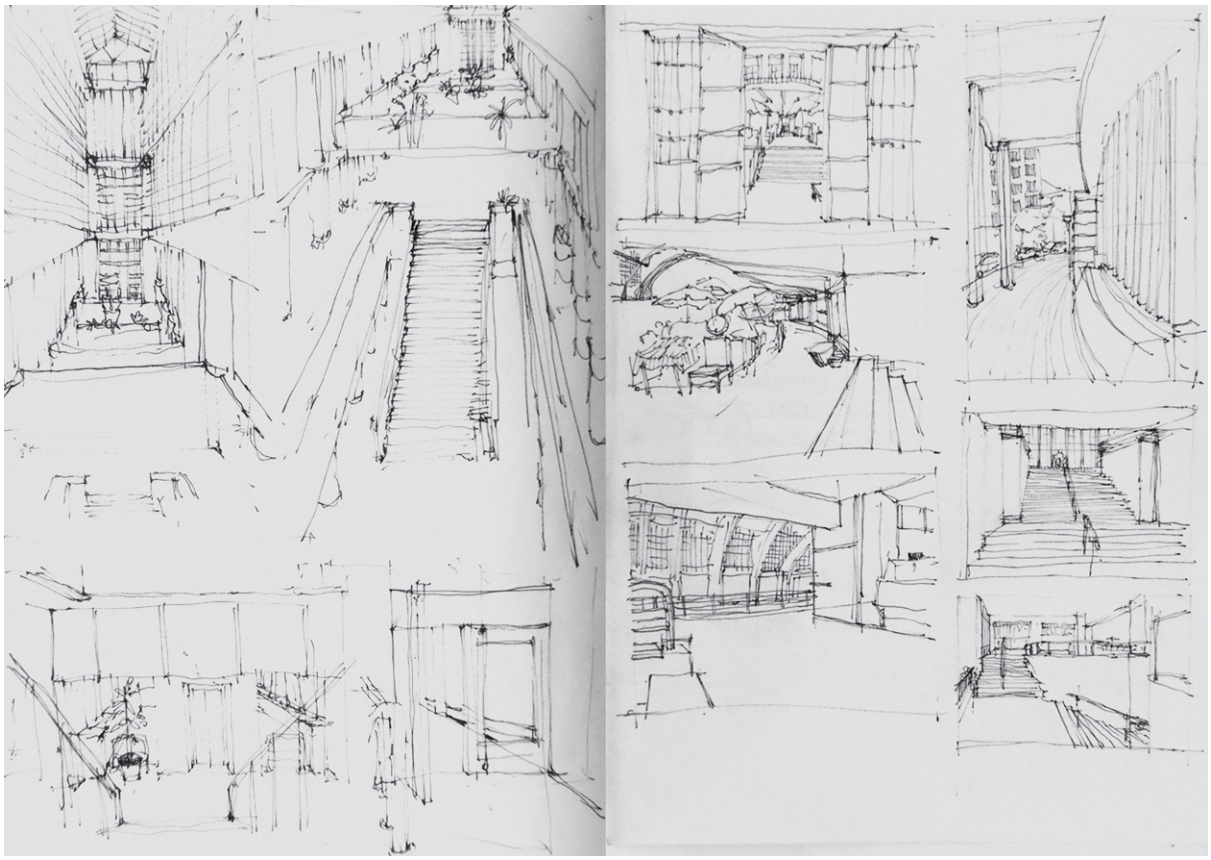


Figure 33. Example of an exercise, FAUP, 2017

Figure 34. Student's graphic notebook, FAUP, 2011

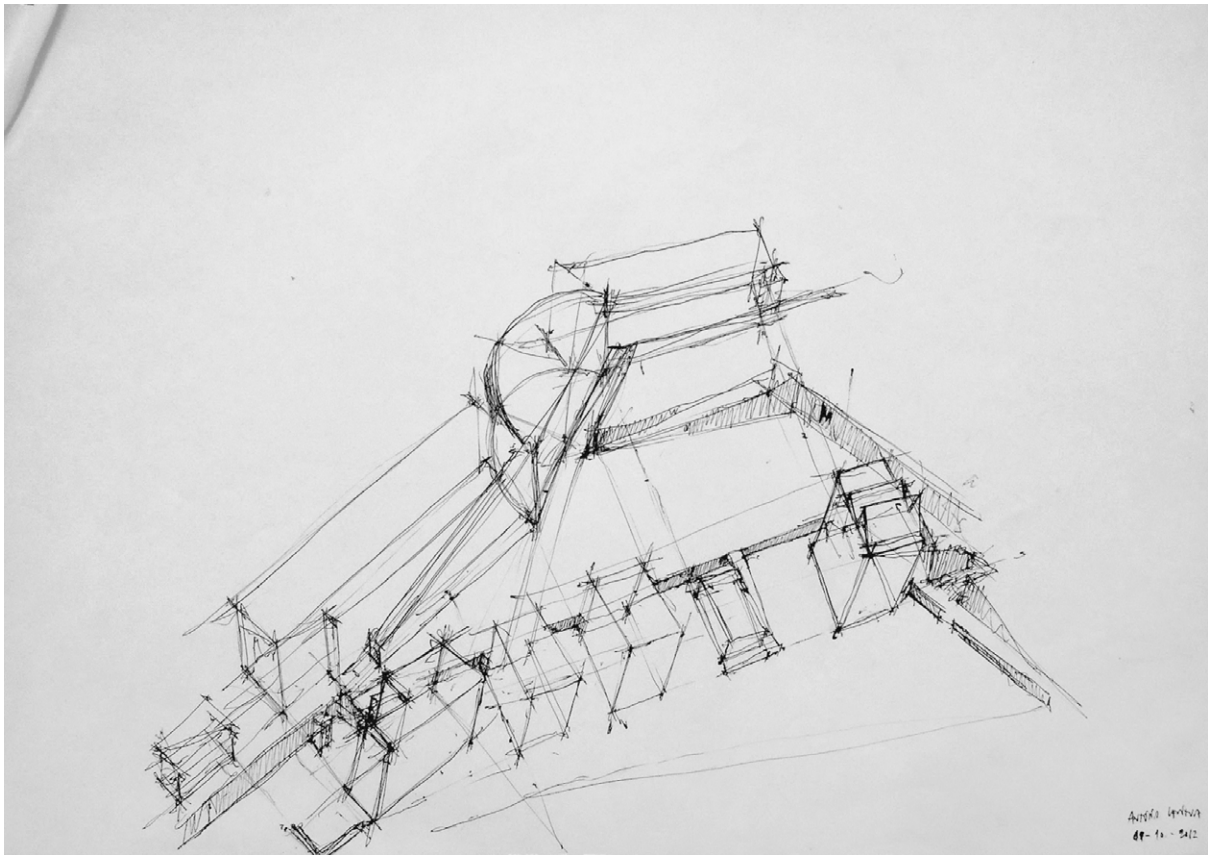
modes of drawing, perspective, and visual field. Examples of exercises from previous years and drawings made by instructors themselves are shown, as well as drawings by artists or architects, to develop in students a "visual culture." There is also a component of work carried out by students outside of classes. Some exercises are placed by instructors and are mandatory, such as the creation of a graphic notebook (figure 34). Students are also encouraged to resume or redo some of the exercises developed in class.

An important didactic moment in drawing courses is the intermediate evaluation. These moments are established at the beginning of the academic year, on specific dates, and are used to assess the students' work, not only quantitatively, but qualitatively. Students receive individual critiques of their productions and an assessment of their progress. At the same time, they can learn about the work of their colleagues, as these sessions are collective, and the drawings produced by the class are displayed on the classroom walls. Vieira (in Pais 2018) also emphasizes the importance of intermediate evaluation moments. What matters in the assessment is not attributing a value to the student's work, but the possibility of discussing "feelings, notions, ideas, concepts, cultural and poetic values, disappointments and encounters between instructor and student" (Vieira in Pais 2018).

Didactic approach to drawing

At FAUP, the didactic approach to drawing is essentially based on the relationship between instructor and students. At the beginning of each practical class, as already mentioned, the instructor presents the theme and the exercises that will be requested. To provide a demonstration, the instructor either showcases reference drawings or creates one. Following this, each student commences working on the assigned exercise, with the instructor actively observing and guiding the drawing process. The consistent and methodical supervision stands out as one of the key aspects in the teaching of drawing at FAUP.

Since it is up to the students themselves to develop their own work method, the instructor is responsible for enhancing their individual characteristics—some students have a very thoughtful approach, from the point of view of linear geometric construction, others however are more gestural and intuitive—and for guiding them, so that they do not stray too far from what their line of training should be. The instructor must ensure that students are able to identify and act on their own mistakes, that they avoid cognitive formulas or cheats. Several instructors say that it is important to act in real time: the pedagogical effect is much more relevant when the instructor's intervention is made in the student's drawing process.



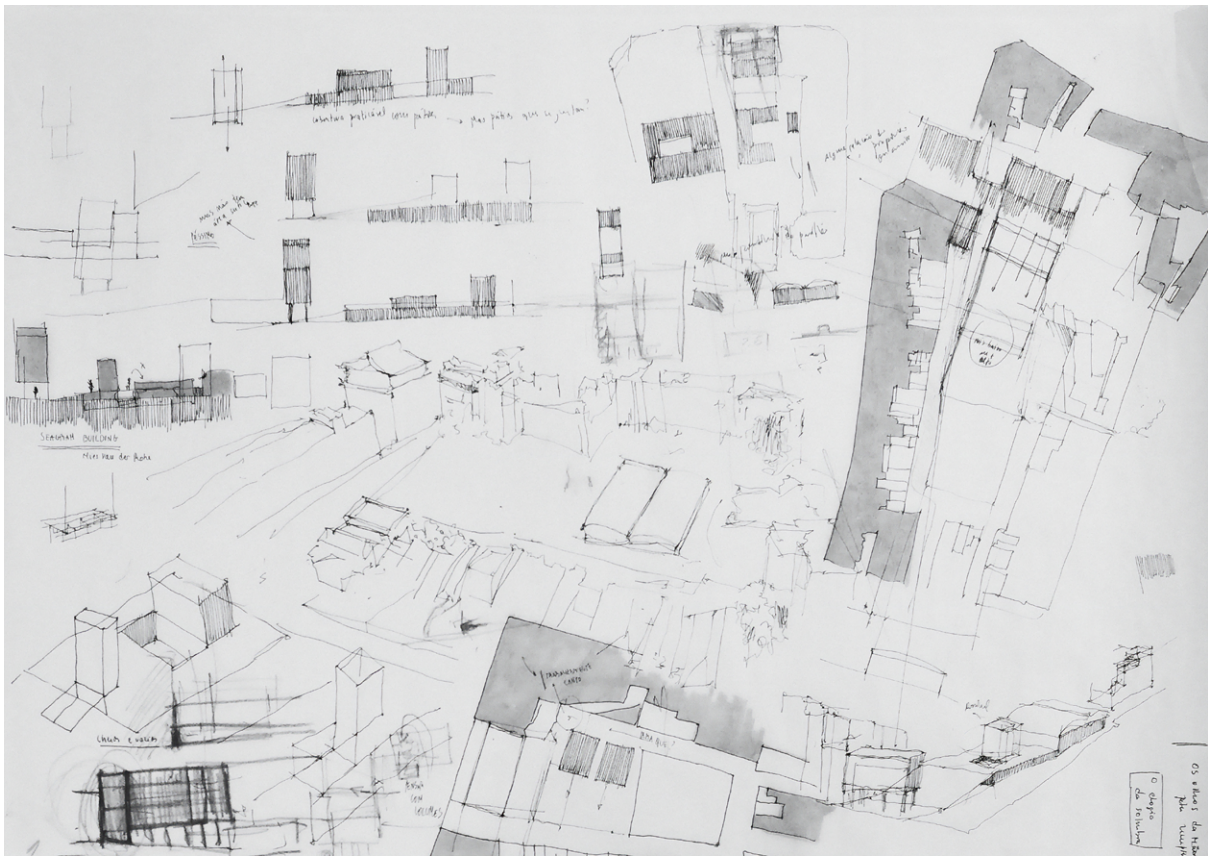


Figure 35. Axonometric perspective with constructive lines, FAUP, 2012

Figure 36. Student's design process, FAUP, 2020

The ways in which the instructor can intervene are varied. The instructor can point out an error or make the students realize it for themselves. In the case of visual drawing, a way for the instructor to reveal the error to the students is to instigate them to look, to realize that there is something wrong between their representation and the real. As discussed by Lyn and Dulaney (2009), a significant part of mistakes made by students in drawings is related to a failure to understand visible reality.

To show how to solve a particular student's difficulty or representative problem, the instructor draws. The transmission of knowing how to draw—which is, in this case, a know-how—seems to take place through example. The example, as Cabau (2016) argues, is not limited to the illustration of a technique or the provision of a model, but the demonstration of a "practical and concrete procedure presented with a pedagogical purpose". It is not a question of the instructor showing "how it is done," but of showing "how he/she does it" (Pais 2018). In fact, as several instructors pointed out, it is a necessity for them to draw during the drawing classes.

This exemplification can be done in several ways. The instructor might stand beside the student and provide annotations on their drawing, or alternatively, invite the student to stand and take their place. It is also worth noting the place where the instructor draws, that is, some instructors intervene in the student's own drawing, in the margin of the sheet, on the back of the sheet, on a new sheet, in a personal notebook or on the blackboard.

However, most instructors intervene directly in students' drawings, either to make subtle notes or expressive transformations. Therefore, some drawings end up "chewed" or "dirty" (Quadros in Pais 2018). This approach seems to influence students from the point of view of disinhibition: drawing is seen as an exercise, an exploration, and therefore there is no need to be "clean" or "beautiful." It also seems to make students detach themselves from their own production. In fact, instructors encourage students not to erase constructive lines (figure 35), not to erase construction errors in the composition, but nevertheless to correct the drawings.

As Quadros (in Pais 2018) refers, the class should be understood as the "place for the error", where there is the opportunity to make mistakes, to fail, and to learn from it. It is important that the students are willing to make mistakes, that they accept the risk, that they are not inhibited, so that they can learn from this experience. The instructor must be able to create the right learning environment so that students feel confident and stimulated.

During monitoring, the instructor can address the class to show an exemplary drawing of a student—either to show a recurring error or difficulty, how a problem was overcome or how a technique was applied. At the end of the class, the instructor often sets aside a few minutes to discuss with students. These discussions can take place around an exemplary drawing made by a student, or the class can be asked to post the drawings on the wall. Thus,

although work in drawing courses is individual, students are encouraged to follow the work of their colleagues. In addition to being important for the students' training, the contact with the work of others, this is a way to strengthen the sense of group and strengthen relationships, which contribute to building a more profitable teaching environment.

At various times, the instructor explains to the class what the general purposes of the subject are—for example, how the drawing will be important in/to the design process—, the objectives of each phase of work or exercise. The instructor introduces students to the purposes of the drawing course and how the type of approach they follow will fulfill these assumptions. As stated by Ortega y Gasset (2000), to truly learn, the student should recognize the immediate need for that knowledge. Thus, the function of the instructor is not only to teach the subject, but to show the students the need to learn that subject.

5.2.3 Considerations

In his famous book on Edgar Degas (1948), Valéry states that it is very different when we look at something with a pencil in hand. In that moment we realize we do not know the things closest to us, like the nose of our best friend. Valéry thus highlights an idea already widely discussed by various authors and educators: that freehand drawing, when used to depict visible reality, enhances our observational abilities. This is because, to represent something, we need to understand that thing, shifting observation from a passive to a more interactive and even creative process between the observer and reality (Lynch 1964).

Vieira (1995) suggests that the prolonged and attentive observation required by drawing reveals unsuspected levels of relationship between things, beings, and their entities. It is not just about assimilating reality but representing and therefore understanding it. Thus, drawing becomes a complex process of selection, choice, and synthesis, leading Le Corbusier (in Danièle 2015) to assert that learning to draw is, concurrently, learning to see.

Perhaps that is why, despite losing relevance in architecture curricula today, observational drawing initially survived the advent of photography, which, as a recording and documentation tool, is incomparably more efficient. For instance, since it was founded, observational drawing has been part of the curriculum for all students at MIT, including those in health and biology courses (Kaiser 2010).

How should this be explained? Santiago Ramon Y Cajal, a prominent neurologist from the late 19th century, stated that the act of depicting something disciplines and strengthens the attention, compelling us to cover the whole of the phenomenon studied, and therefore preventing, details form escaping our attention which are frequently unnoticed in ordinary observation (in Pallasmaa 1994, 84).

Drawing differs significantly from photography, which captures a literal snapshot of reality. As Berger (2008) notes, drawing is a temporal image, crafted through multiple gazes on the same object over a necessarily extended period compared to a photograph. Additionally, in observational drawing, the resulting image is never a direct representation of reality; rather, it reflects our interpretation of it. It is always the outcome of a more or less intuitive, more or less rapid analysis of reality that ultimately transforms into a new image, imbued with traces of the observer (Valéry 1948).

In some cases, drawing has preserved a significant connection with education. At FAUP, drawing seems to assume the role of a didactic instrument. Students, in addition to learning to draw, learn through drawing. As Távora (1991) refers, in the absence of a culture of explicit theoretical elaboration, drawing has been the support for the continuity of the school, as an expression of a unified thought about what the reflection and practice of architecture should be. Drawing, as an autonomous form of language (Siza Vieira 2009), is how the interaction between instructor and student is established, a key factor in teaching and learning in both drawing and architectural design courses.

With this section it was intended to study the formal teaching of freehand drawing in architectural education, considering the case of a particular architecture school. The two drawing courses at FAUP were analyzed considering their theoretical assumptions, the curricular context, the organization of classes, and the didactic approach.

It is necessary to consider that the teaching and learning of drawing at FAUP is not limited to what is developed within the drawing courses, but in the entire curricular plan. Especially in architectural design courses, the approach of the instructors is largely based on the same assumptions followed by instructors of drawing.

However, this teaching model faces some difficulties. It is usual for students to reduce or even stop drawing by hand after starting to use digital instruments. Moreover, students do not understand the general didactic strategy of the first two years, during which they cannot use the computer, regularly subverting and trying to circumvent this rule. Perhaps this is to be expected of digital natives in an analog setting.

A difficulty in the articulation between instructors and students seems to lie here: in the fact that the students do not understand the usefulness or purpose of certain didactic practices. Even when explicit, the student may not recognize the importance instructors place on it. An important future work would be to understand the correspondence between the aspects developed by instructors in the drawing course and the effects on the students' work process in the architectural design courses.

5.3 Drawing and design

5.3.1 Outline

In this section the relationship between design studios and drawing courses within the Integrated Master's Program in Architecture at FAUP is analyzed. The section begins by examining the curricular organization of the program, highlighting the harmonization between the courses and the pedagogical approach employed. Particular attention is paid to the intersection between design studios and drawing courses in the first two years of the program, with a focus on the prominence of freehand drawing and the prohibition of computer use during this period. Furthermore, the crucial role of freehand drawing in the design process, including its continued usage in design critiques throughout the five-year program is explored. The section concludes by discussing the significance of freehand drawing as a means of fostering interaction between instructors and students during the design process. Both the drawing courses and design studios were monitored between November 2020 and March 2021, which allowed for the monitoring of both in-person and online teaching.

5.3.2 Findings

Curricular context and organization

The analyzed courses are part of the integrated Master's degree in Architecture at FAUP, which in total lasts for five years. The design studios are mandatory and held on an annual basis, so there are five studios, one in each academic year, called *Projeto* 1, 2, 3, 4 and 5. The workload of the five studios is the same, 12 hours per week. Among the five design studios there is a curricular alignment, both in terms of topics covered, pedagogical objectives and teaching approach. Thus, the general organization of design studios is not decided year by year by the responsible instructor but is defined collectively.

The two drawing courses are also required to be attended annually and are taught in the first two years of the Master's degree, called *Desenho* 1 and 2. In terms of workload, and consequently, in terms of curricular weight, *Desenho* 1 is quite considerable, when compared to design studios, with 8 hours per week, while *Desenho* 2 is 3 hours in length. Also, in the case of the two drawing courses there is a previously established curricular alignment, with a program that must be completed by all classes.

Horizontal and vertical intersections

It is possible to verify by the context and curricular organization, that the most direct intersections between the design studios and the drawing courses—which here are called horizontal intersections—happen in the first two years of the Master's program, where they are simultaneously taught. In addition to the coordination that exists between courses, it is also during this period that students need to follow a singular rule of this school, which is the prohibition of computer use in design studios. According to this rule, students must produce all design representations made by analog means, where freehand drawing plays a key role. While in the drawing courses students are learning the fundamentals of freehand drawing—through the systematization of the instrumental and expressive component, the different ways of drawing and the various representation systems—in the design studios they are making the practical application of this learning.

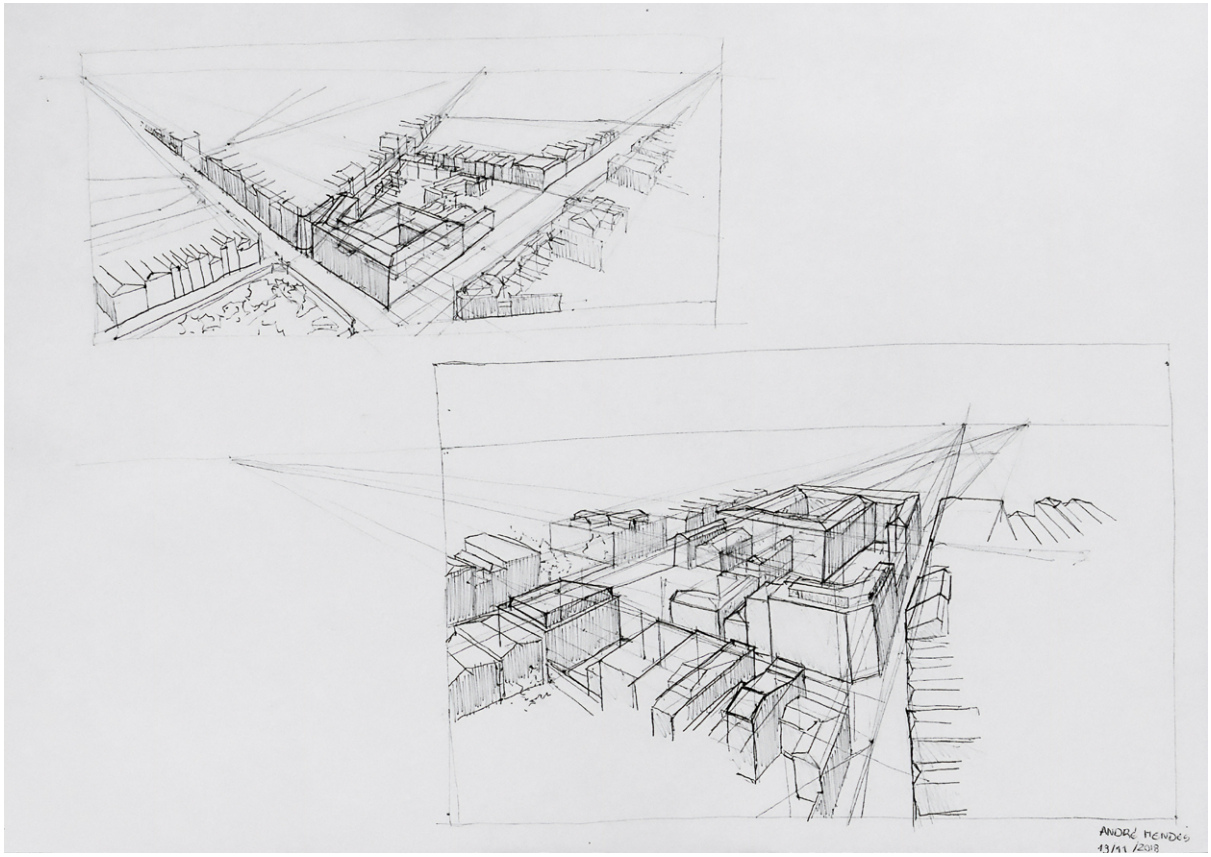
In the first year, the intersection between design studios and the drawing course takes place mainly at an instrumental and procedural level. In *Projecto* 1, for example, students are required to use visual drawing to approach the intervention site, as they do in *Desenho* 1. The entire design process is also supported by freehand drawing, and complemented by physical models, where in addition to the technical representations, studies of shape and volume are carried out.

In the second year, however, there is a direct link between the exercises of the two courses. In Drawing 2, students produce drawings of the intervention site used in *Projecto* 2, such as perspectives with one or two vanishing points, impressive surveys of the plans and elevations of the site and the surroundings, axonometries and aerial perspectives. This material is then used in both courses and serves as a basis for experimenting with design solutions.

In these first two years, design studios have then explicit intersections with drawing courses. However, there are also intersections throughout the different academic years, more discreet and subtle (Dorta, Kinayoglu and Boudhraa 2016), which here are called vertical intersections. These intersections have to do with a particular use of freehand drawing in the design process, but also with the teaching approach itself, as will be explained below.

Freehand drawing and design teaching

As already mentioned, during the first two years, students are required to use only analogue means of representation, which are essentially freehand or technical drawing and physical



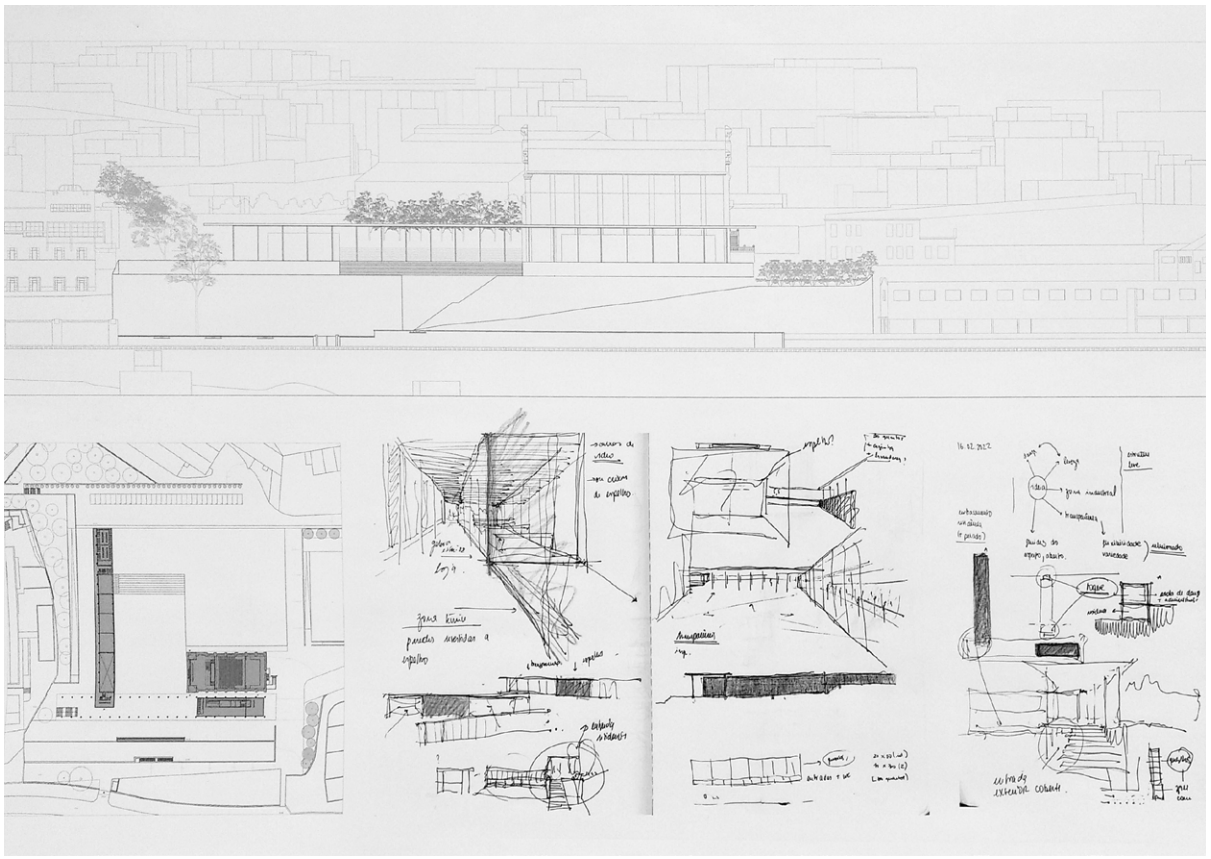


Figure 37. Aerial perspectives of the intervention site, FAUP, 2020

Figure 38. Poster with analog and digital representations, FAUP, 2022

models. In addition to the design drawings, where freehand drawing is used as a thinking resource, students are led to resort to freehand drawing for the recognition of the intervention site, producing perspectives with one or two vanishing points, aerial perspectives, axonometric perspectives, and impressive surveys (figure 37). It is assumed that during these first two years, the propaedeutic character (Pais 2018) of the design studios is not only related to the acquisition of instrumental capacities, the dexterity and mastery of the different representation systems, but also the indication of a method of designing (Mendes in Portas 1986).

After these first two years, the use of freehand drawing as a design instrument is significantly reduced. Having the freedom to choose the forms of representation they prefer; many students start using CAD and BIM software. The freehand drawing used as a way of thinking, in the exploration of design solutions, however, continues to be used. No longer for the entire class, but for a significant part of it. It is common for students to associate freehand drawing with other forms of representation in the design process, especially digital ones, using one or the other according to specific needs (figure 38). There is a cycle in the elaboration of the design project, which consists of the production of digital representations, which are then printed, and manipulated through freehand drawing, using tracing paper or drawing directly on the prints.

Freehand drawing is also used as a means of interaction between instructors and students, during the so-called design critiques (Milovanovic 2019). Not just for the first two years, when students are required to just use freehand drawing, but for the entire five years of the Masters. Even when students are working almost exclusively with digital media, freehand drawing is always used in design critiques. It is very common for instructors to ask students to print out the design elements so they can draw on it. Several instructors mention that this is a kind of necessity, since without direct demonstration through freehand drawing, critiques would be much less effective for students (Pais 2018).

One manifestation of the importance of freehand during design critiques was during the pandemics. Despite the discussions taking place through the screen, instructors and students quickly began to resort to drawing tools, using the mouse to interact and manipulate the students' productions.

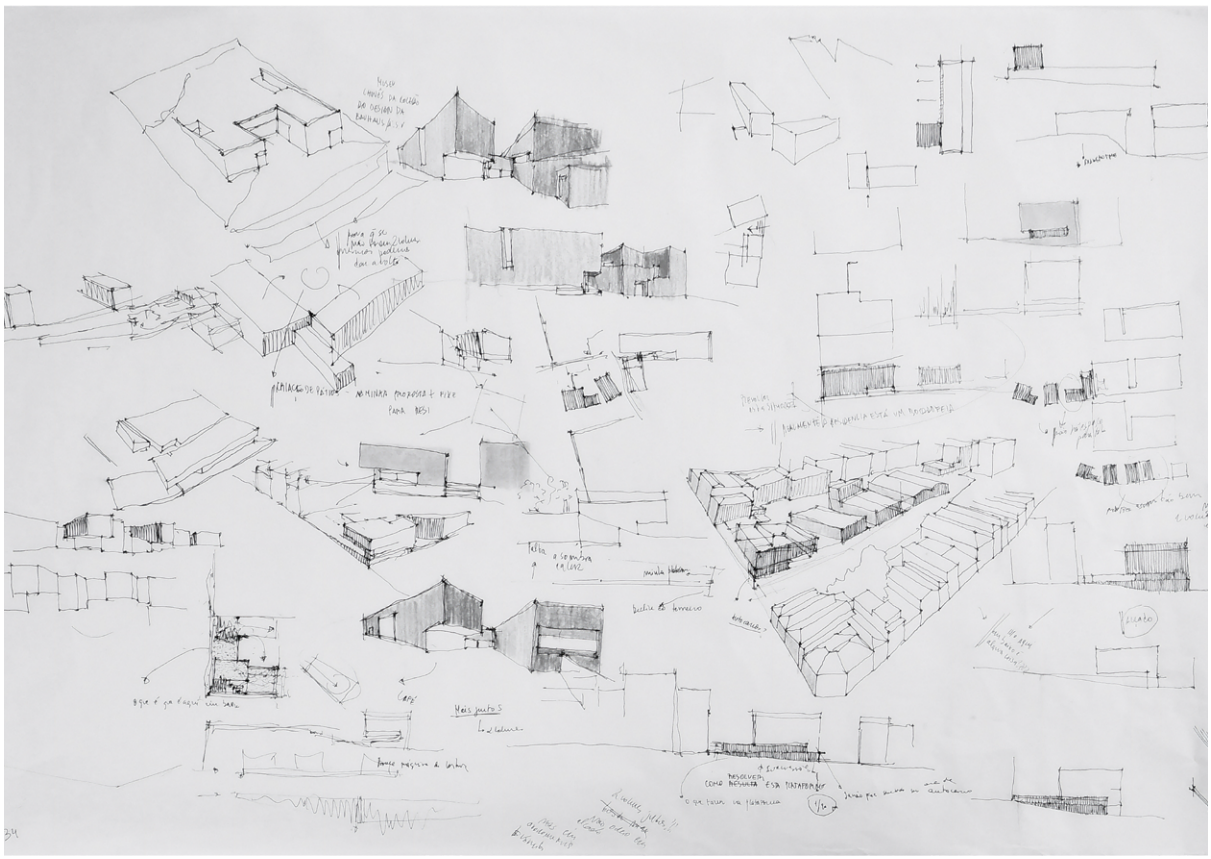


Figure 39. Exercise for the recognition of the intervention site, FAUP, 2022

Figure 40. Student's design process, FAUP, 2020

5.3.3 Considerations

Freehand drawing as a design instrument

Considering the horizontal and vertical intersections analyzed, as well as the didactic approach in design studios, it is possible to recognize two roles of freehand drawing in design teaching at FAUP. The first is the role of freehand drawing as a design instrument. In this school, the training of the students in freehand drawing is considered fundamental, and therefore there is a large investment in the first two years of the integrated Masters. Not only because students must attend two annual and mandatory drawing courses, but also because they are subject to the rule of not using digital media in the design studios. It can thus be seen that there is a direct coordination between courses for a common objective, in this case, the teaching of a design process or methodology based on freehand drawing (Fernandes 2015).

While in the drawing courses the technical and expressive dimension of drawing is focused, in the design studios students learn how to apply this knowledge. Students then use freehand drawing: as a perceptive tool to approach the intervention site (figure 39); in the process of form finding, definition of design ideas, volumetric and spatial studies (figure 40); to make technical representations of the design project, such as plans, sections, and elevations.

Despite drastically decreasing its use after the first two years, freehand drawing continues to be present in the design process of many students, especially in the so-called study drawings (Herbert 1988). These study drawings are often crude and dirty, produced quickly, as an extension of thought (Goldschmidt 2017). Freehand drawing can then be seen as the starting point of students' training, a kind of prerequisite, which gives them instrumental and technical skills of spatial perception, representation, conception, and communication, which constitutes a method of designing.

Freehand drawing as a didactic instrument

There is a second role of freehand drawing that can be recognized in design teaching, and that is its use as a means of interaction between instructors and students in the teaching and learning process, that is, as a didactic instrument. As mentioned, students start the Master's program with a propaedeutic period, where they have an intensive training in freehand drawing. On the one hand, because there is a conviction in this school of the importance of freehand drawing as a design instrument, due to its several qualities as a

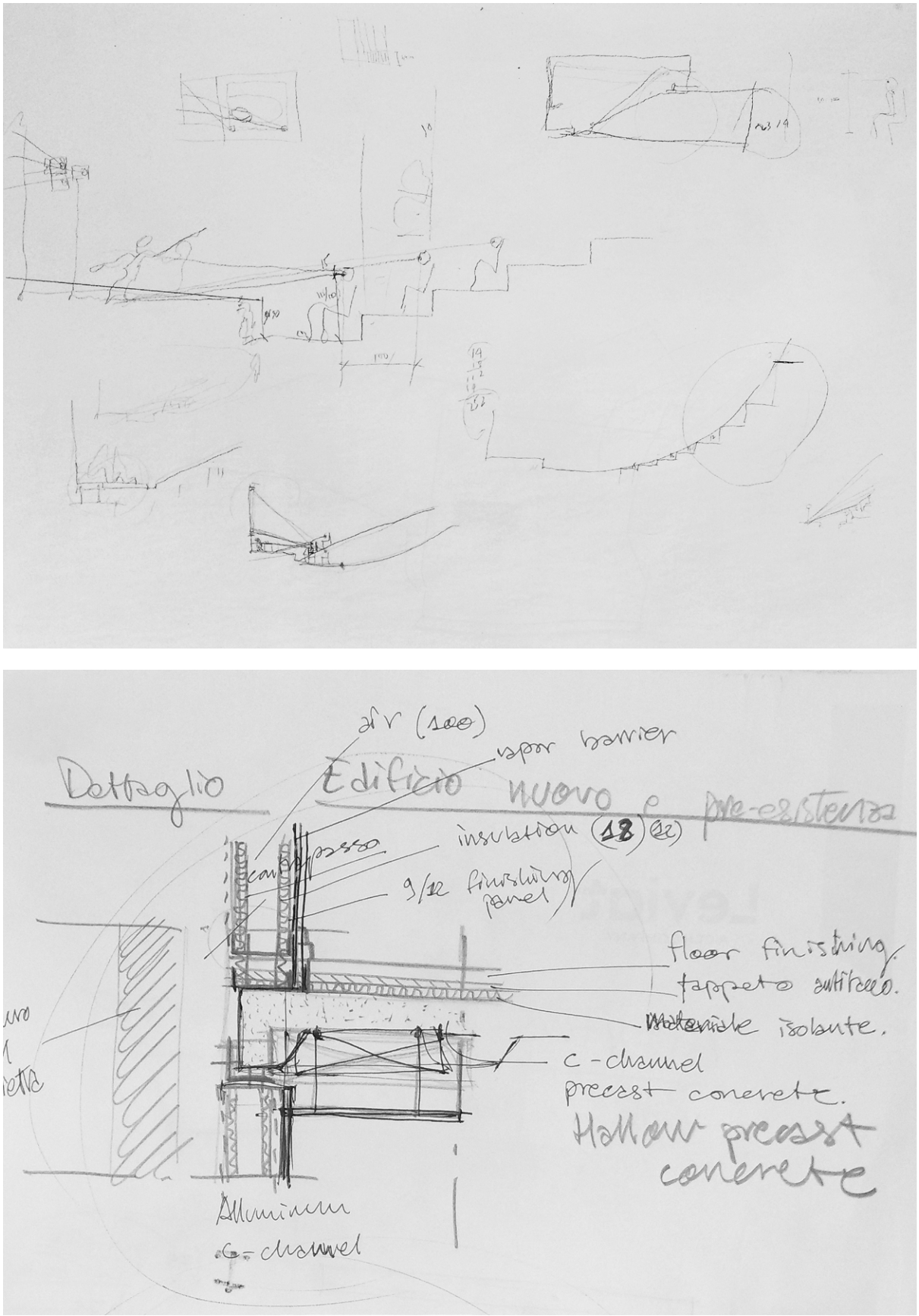


Figure 41. Instructor's drawing explaining a design issue, FAUP, 2022

Figure 42. Student drawing to clarify a constructive question, FAUP, 2022

form of representation. On the other hand, because freehand drawing plays a fundamental role in the learning process itself (Carneiro 2017).

At a more immediate level, the teaching of freehand drawing corresponds to a didactic strategy, whose objective is to circumvent the enormous heterogeneity of students when they arrive at university. Considering that they all have very different backgrounds, from arts, humanities, sciences and technical courses, this is a way to put them all on the same starting point, with the same knowledge and resources (Quadros in Pais 2018). Moreover, students receive training similar to that of design studio instructors. This aspect is very important, because the fact that they share a representative and procedural literacy—in other words, metaphorically, they share the same language—making it possible to create a unique "trading platform" between them (Milovanovic 2019).

This form of interaction is significant in the early years, when students still have little autonomy, but also throughout the Master's program. If, as it was mentioned, the use of freehand drawing in the most advanced years reduces substantially, its use in design critiques is never reduced. During the five years of the Masters, passing through all the design studios, it is visible how instructors and students actively resort to freehand drawing to support design critiques. Even when students are working with digital representation forms, instructors ask them to print the design elements before the design critiques, so that the criticism is not merely verbal or gestural.

The fact that instructors draw during design critiques is not a particularity of FAUP, since at other schools, even where freehand drawing is not part of the curriculum, instructors often draw. However, what happens at FAUP is that students also draw. Most of them resort actively and systematically to freehand drawing, which makes it form of dialogue with instructors (figure 41). They can use freehand drawing to quickly ask questions, to clarify a design ambiguity, in short, to discuss (figure 42).

Students' drawn productions also play an important role in, as an expression of their knowledge and pedagogical situation (Carneiro 2017). Whether the drawings made during design critiques, in real time, or the drawings made during the design process, are crucial for instructors to track their progress. This is done for an extended period, for one entire year, with different points of intermediate evaluation, where both instructors and students consider the progress made so far. It is also an opportunity to recognize the relationship between didactics and the results achieved, which is an important aspect of the learning process, because, as mentioned by Quadros (in Pais 2018), one of the difficulties of this type of didactics is the mismatch between awareness of learning and its experience.

Teaching and learning vulnerabilities

Finally, after characterizing this way of teaching and learning, it is important to point out some of its vulnerabilities. They can be organized into two groups. The first group has to do with a difficulty for students to understand the school's didactic strategy, as already mentioned, about the importance given to freehand drawing in the first two years, associated with the prohibition of digital media. Not all students are able to understand the purpose of this option or agree with it, which can be problematic, as this can condition their readiness to learn (Ortega y Gasset 2003). There are cases where students even subvert the rules set by instructors, using AutoCAD, for example, then printing and reproducing the drawings by hand. Among the students, there are those who consider this way of learning old-fashioned, and that the importance given to freehand drawing in this school does not make sense. They usually argue about the professional issue, that is, that the university should prepare them more directly for professional life.

Another aspect has to do with the importance given to the representation as the center of didactics, and that can lead to an overvaluation and autonomy of the freehand drawing to the design itself. In some cases, students tend to confuse the design with its representation, and design qualities with graphic qualities. As Mendes (in Portas 1986) states, the formal exploration or production of images without critical awareness, not understanding design in its relationship with reality, removes all the pedagogical value of design studios, making these simple graphic exercises or demonstrations of virtuosity.

Regarding the second group of vulnerabilities, it is related to an imbalance in the relationship between instructors and students, which is one of the pillars of this form of teaching. One of the aspects to consider is the subjective component of the criticism made by instructors. Besides objective questions, in which instructors may argue about typologies, constructive procedures, regulations and legislation, there is an aside from criticism that is entirely subjective, referring to their personal experience and sensibility (Nicol, Pilling and Pilling 2019). For this reason, it sometimes happens that students do not accept criticism as valid, considering it just the instructor's opinion.

Moreover, it may also happen that students see the instructor as the last criterion to validate a design decision. This leads students to loss of autonomy, annulling their critical capacity, and making them unable to move forward without the instructor's approval. Another issue has to do with the personalization of this way of teaching, overlapping students' performance and work with themselves. At FAUP, where teaching is about individuals—and where the idea of the author architect is still very present—students may personalize a failure, affecting their self-esteem, leading them to avoid risks. This is problematic because,

as referred to by Lawson (2005), mistakes and failures are a crucial part of the design learning process.

The educational significance of freehand drawing

This section aimed to understand the role of freehand drawing in architectural design teaching and how it influences or determines the teaching approach at FAUP. Either by the curricular intersections of the design studios with the drawing courses or by its presence in the design critiques, it seems possible to argue that freehand drawing has a crucial importance in the way architectural design is learned and taught in this school. As such architectural design is learned, as was discussed previously, all students in the first two years learn freehand drawing and at the same time learning to apply said freehand drawing into their design process, thereby it functioning as a general base or foundational training.

Thus, freehand drawing becomes for all students the first and most important design instrument, which will later be complemented with other forms of representation. As it is taught, freehand drawing in this school is also a didactic instrument, used as a means of interaction between instructors and students in monitoring the design process. The option of teaching freehand drawing does not seem to contradict or compromise the new possibilities brought by digital media, but rather the opposite, enhancing the students' fundamental skillset.

As mentioned, students often use freehand drawing in addition to CAD drawing or digital and physical models, acting as a structuring and articulating element between the various forms of representation. An important future piece of research that might be undertaken would be to analyze design teaching in a school where freehand drawing is not part of the curriculum, thereby allowing a point of contrast. Considering that even in these cases, as referred by Gero and Milovanovic (2020), instructors often resort to drawing, it would be relevant to understand what changes in and with the interaction with students, and consequently in its pedagogical effectiveness.

5.4 Drawing and online teaching

5.4.1 Outline

The Covid-19 pandemic has dramatically impacted all aspects of life, including education. In the field of architecture, the pandemic has presented significant challenges, particularly with respect to teaching design studios and practical classes. Schools and universities

worldwide were forced to rapidly adapt to new public health measures, which required the implementation of non-presential teaching modalities. These changes have had a profound impact on the way that architectural education is conducted.

In this section, we examine the impact of the pandemic on the teaching of architectural design, with a particular emphasis on design critiques and representation. We analyze the various teaching modalities that were implemented during the pandemic, including non-presential and mixed modalities, and investigate how design critiques formats evolved. Through this examination, we highlight the challenges that instructors faced in effectively monitoring and providing feedback to students' work. This section illuminates the obstacles that instructors and students encountered in the aftermath of the pandemic and the innovative strategies that were used to surmount them.

Conversations played a crucial role in complementing dimensions that were inaccessible to observation, such as the dynamics of students' work outside of design critiques. Online teaching facilitated the recording of student productions and graphic interactions with instructors, without disturbing the flow of the class, which was always a problem in regular classes. The design studios were followed between November 2020 and June 2021.

5.4.2 Findings

Teaching modalities

Toward the end of the first semester of 2019-2020, the pandemic emergency required schools to immediately adapt to public health measures. At first, schools were closed, and a non-presential teaching modality was adopted. As expected, the main challenge within architectural education was the delivery of practical classes, such as architectural design or hand drawing. At the end of the so-called "Covid semester," an attempt was made to find a hybrid solution, the mixed modality, which would allow the practical classes to be carried out in person and the theoretical ones at the distance.

Non-presential modality

When the non-presential modality was adopted, the organization of design studios did not undergo significant changes. Didactics, although mediated by the computer, followed the same approach. Instructors continued to monitor the students' work individually, with the rest of the class watching or working. To follow the students' work process, and not just the results brought to design critiques, instructors asked all students to place the process material in chronological order on a class computer hard drive—such as plans, sections, elevations, perspectives, or model photos. This was a way for instructors to perceive the

path taken by the student in the development of the design idea. Students were also encouraged to go to the drive and see their colleagues' work.

With the virtual classrooms, where practical classes took place simultaneously, there was an improvement in the articulation between courses—students could leave and enter, speaking with the instructors of architectural design, construction, or structural systems courses.

It should be noted that the non-presential modality represented a major challenge for instructors and students. The instructors had an increased workload, going beyond normal teaching hours, to be able to effectively monitor the work of the students. A lot of time in class was wasted with technical problems on both sides, delays, or breakdowns in the internet connection.

Mixed modality

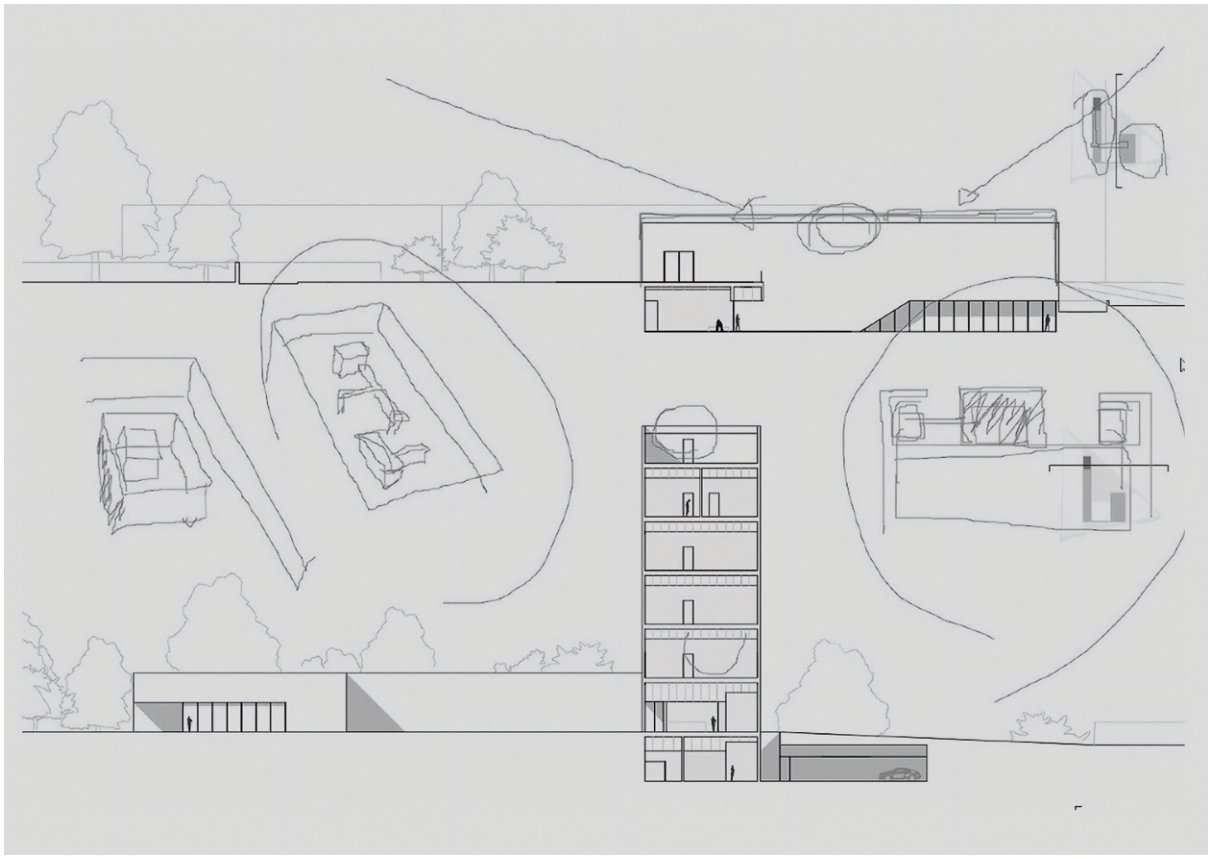
With the mixed modality paradigm, the practical classes were held in person, and the theoretical at the distance. The planning of the courses was adapted so that the didactic moments whose presence was more decisive took place at the beginning of the academic year, such as the launch of the exercises, collective visits to the intervention site or to a reference building or urban area. There was a feeling of constant uncertainty, and it was common for the instructors to recommend students to prepare for the inevitability of new confinement due to likely upcoming changes in government movement directives due to the pandemic.

Considering the distancing rules, the classes of about 25 students were divided into two rooms. The same instructor had to follow the students' work in two different rooms. This raised problems when the instructor needed to speak to the entire class.

There was also a need to ensure the monitoring of the students who, for some reason, were confined. The instructors needed to dedicate extra-class time to these confined students, in a non-presential modality. Although the approach to design critiques was the same as in the pre-pandemic period, the health restrictions did not allow students to follow the sessions effectively. When the instructor was following a student's work, his colleagues could not get close. This was quite problematic since an important part of design teaching is based on knowledge of the colleagues' work.

New mixed modality

In both POLIMI and FAUP, a new design teaching modality was also tested, combining features of mixed and non-presential modalities. The idea is that the practical classes can be in person but guaranteeing online monitoring—not only for students but also for



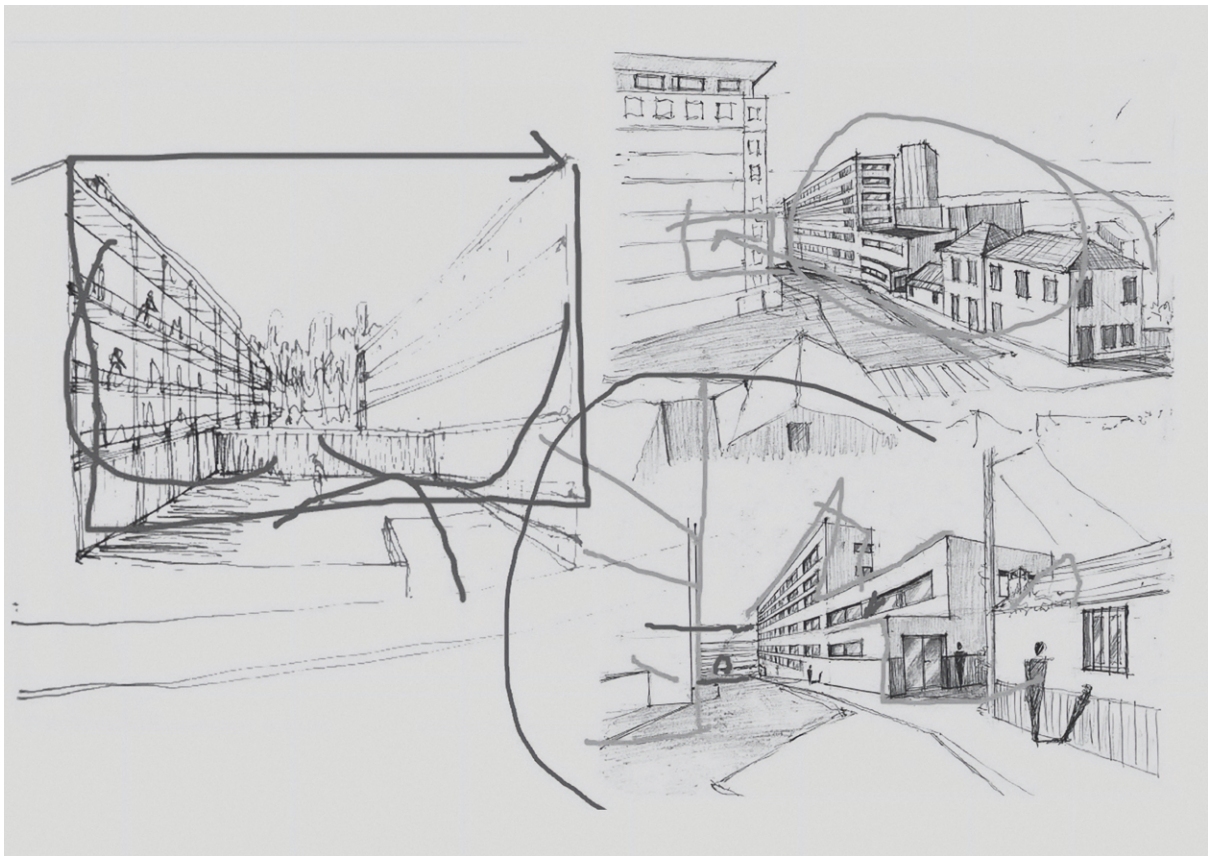


Figure 43. Shared screen: Instructor's annotations on student's work, FAUP, 2021

Figure 44. Shared screen: Student's annotations on his own work, FAUP, 2021

instructors and assistants. To this end, cameras and microphones were installed in the classrooms, as well as a projection screen.

Design critiques and online teaching

The effects of the pandemic on design critiques were mainly relevant in the non-presential classes, since in the mixed modality the monitoring of the students' works followed the previously consolidated approach.

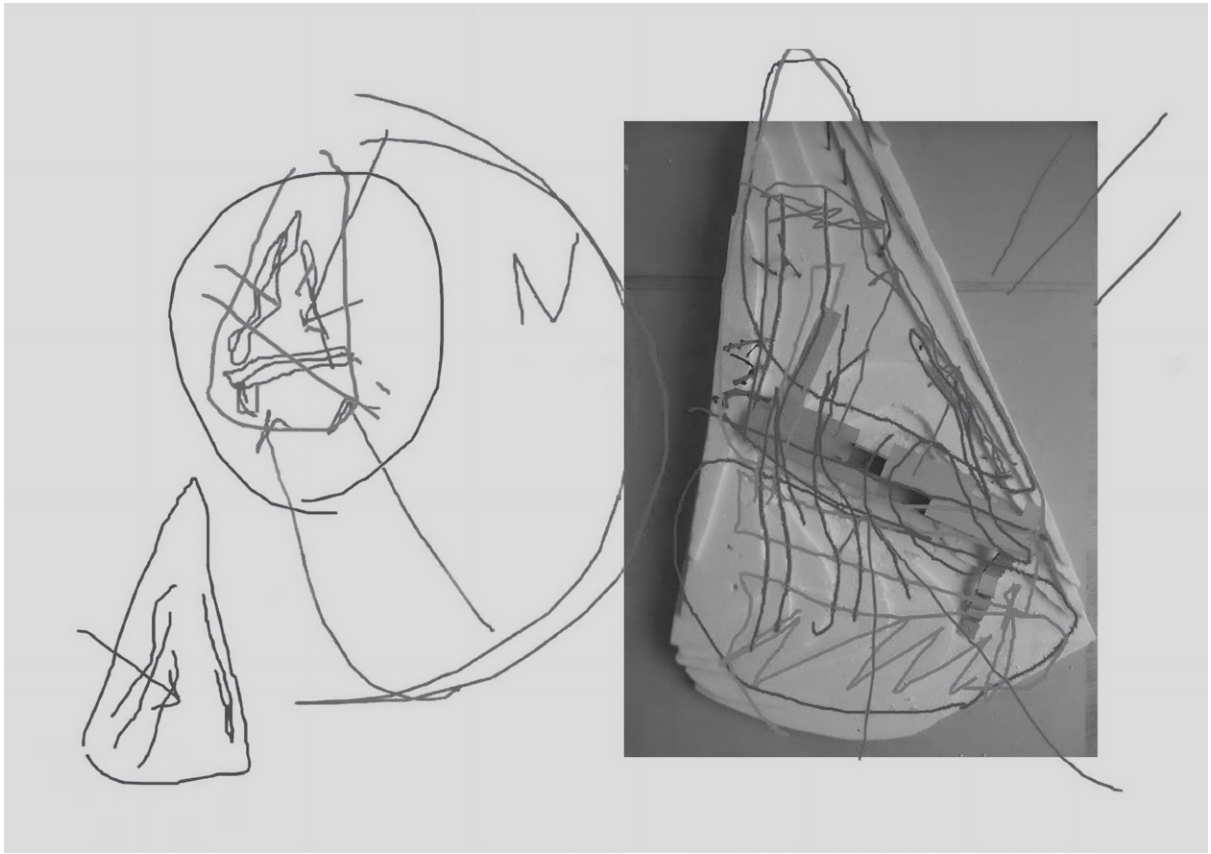
It is possible to identify an evolution of design critiques formats since the adoption of the non-presential modality. At the beginning of the first general confinement, the instructors of architectural design followed and commented on the students' work without intervening in it. Some instructors, on impulse, drew on a sheet of paper and showed it to the student on the web cam. It was a very precarious form of interaction. Other instructors printed students' work to draw on it. Then they photographed the sheets to show students during design critiques. It was also an ineffective approach. At a certain point, some instructors started using digital platforms—such as Zoom—which allowed them to annotate or to draw on the shared screen. Instructors used the mouse to make notes about the students' work, and often asked them to do the same. According to some instructors, it seems that students have gained some sense of participation or disinhibition with this approach, not only commented but drawing more actively during the criticism.

Although it was difficult to draw with the mouse, it was possible, and from the first annotation strokes, instructors began to draw plans, sections and even perspectives (figure 43). Some instructors started using smart phones or tablets to draw, with a digital pen, which allowed them to achieve more impressive results. Sometimes the students themselves, after showing a sketch to the instructor, immediately made a digital note to make their intentions clearer (figure 44).

During the design critiques, instructors also started to draw on the photos of the physical models (figure 45). This novelty was extensively explored and gave the model a new potential as a form of representation. The model, which by its nature is less flexible and dynamic in construction and manipulation, was then complemented with digital drawing.

In fact, distance education has led to the fusion of certain forms of representation, mixing photography, drawing, physical models, 3D models, etc. Figure 46 is an interesting example of this representational mixing: it is possible to see that the base is a vector drawing in AutoCAD, with some sketches in the right corner, some colored digital notes, and a digital red line made by the instructor during the criticism.

Another possibility that was introduced was the manipulation of files under construction through digital drawing, opening a software and intervening directly in it—as an AutoCAD



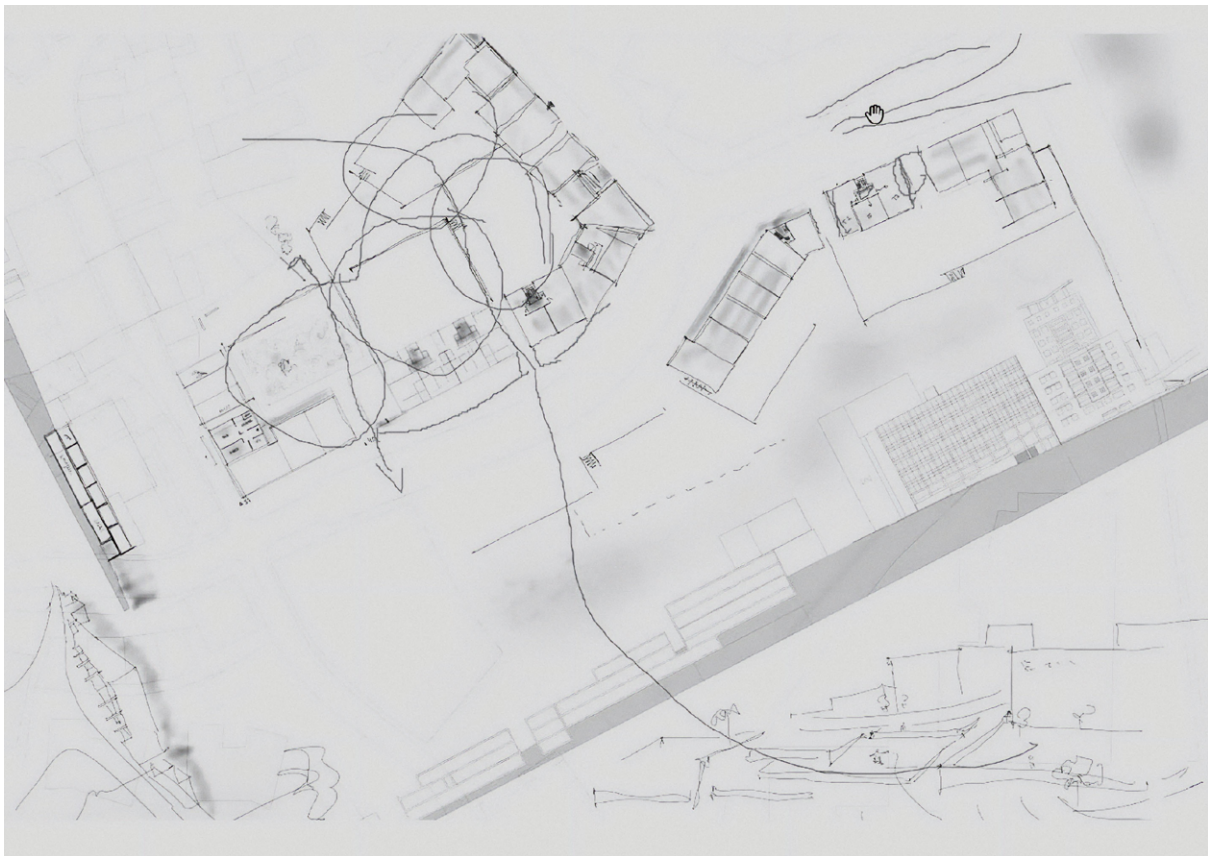


Figure 45. Shared screen: Instructor's annotations on model photos, FAUP, 2021

Figure 46. Shared screen: Mixing different forms of representation, FAUP, 2021

or a Revit file. In the case of Figure 47, the student opened Revit, placed a perspective view suggested by the instructor, and then both drew on the screen. Even in the theoretical design classes, some instructors began to draw on the presentation slides, and sometimes invited students to do the same (figure 48).

5.4.3 Considerations

Considering the effects of the pandemic in the organization of design studios, in the design critiques approach, and in the external forms of representation, it is possible to summarize some of the new possibilities introduced and the losses involved, such as the opportunities and threats for the future of architectural design teaching.

New possibilities

The Covid-19 pandemic has led to several new possibilities in architectural design education. One such possibility is the direct articulation between courses through virtual classrooms. This has enabled more fluid communication and collaboration among students and instructors across different courses, resulting in increased flexibility in the design process. The ease of receiving guest speakers from different geographies to participate in design critiques or lectures has also become much simpler, providing students with exposure to diverse perspectives and experiences.

Another new possibility is the ability for instructors and students to share content and work on a collective drive. This has created a more accessible and convenient way for students to collaborate and share their work, facilitating remote teamwork and knowledge-sharing among students. Additionally, the virtual classroom has enabled students to access course material and content at any time, making it easier for them to revisit and reinforce their learning.

In terms of design critiques, the direct participation of the whole class in individual critiques has become possible, resulting in increased student participation and engagement. The virtual setting has also led to disinhibition, with students feeling more comfortable expressing their opinions and ideas. Furthermore, instructors and students can open the browser during critiques to show a reference design, a constructive detail, or a city segment. This dynamic approach contributes to more thorough and productive design feedback sessions.

In external forms of representation, new possibilities include the use of photos of physical models as a design tool. Additionally, students can now draw directly on files under construction, such as CAD or BIM files, facilitating collaboration and knowledge-sharing in

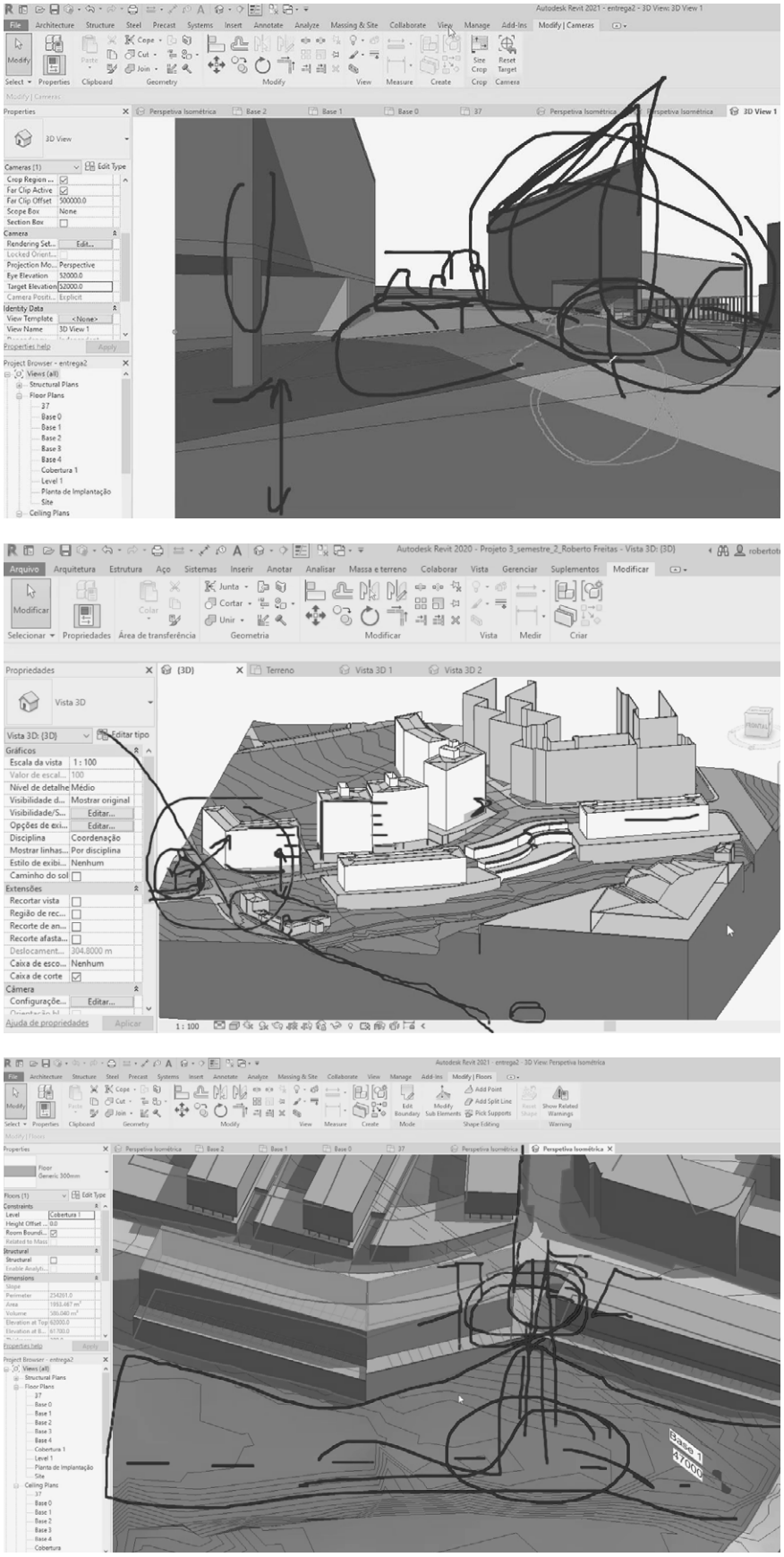


Figure 47. Shared screen: Instructor's annotations on a Revit file, FAUP, 2021

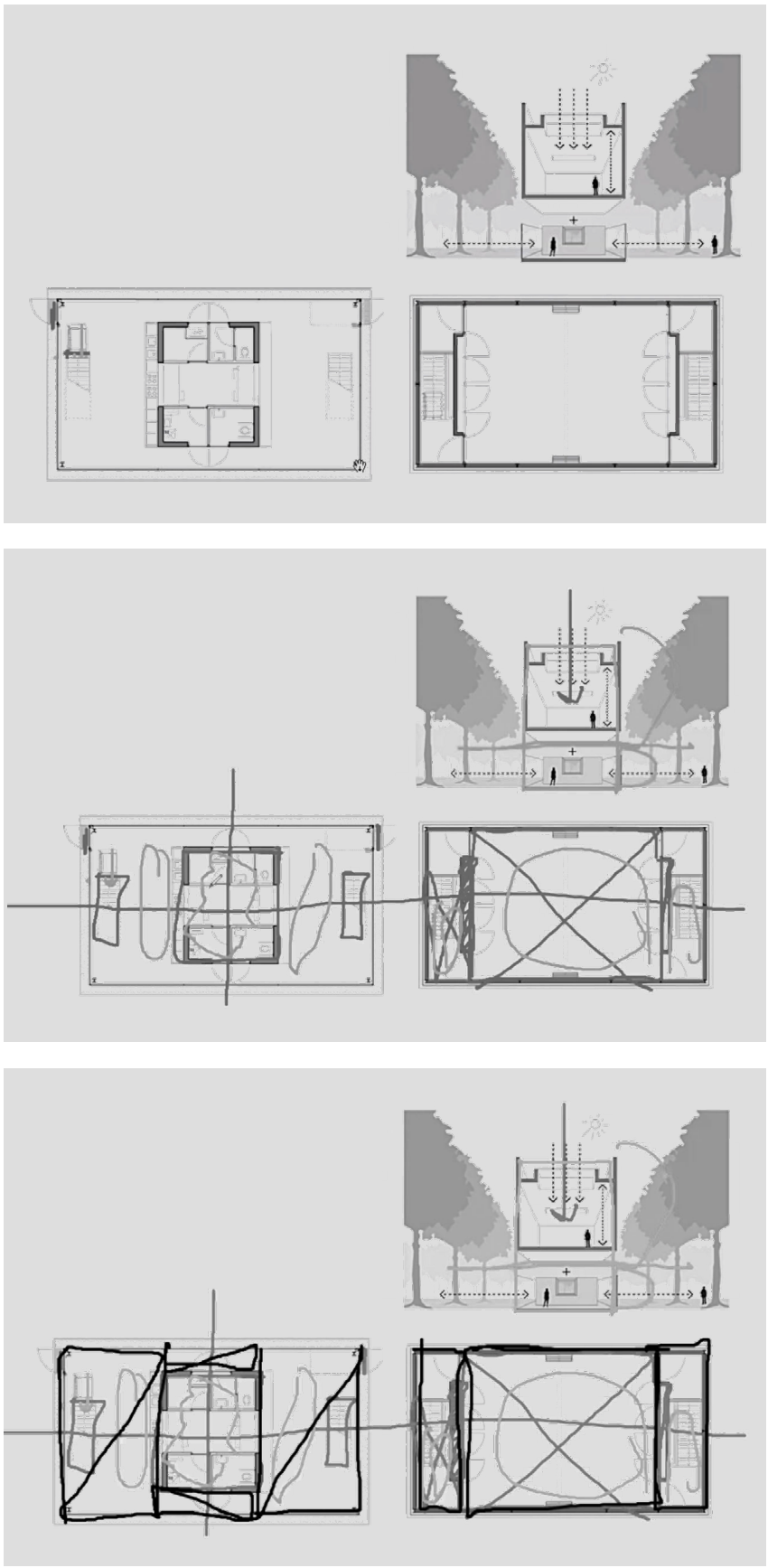


Figure 48. Shared screen: Instructor's annotations on his own presentation, FAUP, 2021

the design process. The pandemic has also led to the use of different forms of representation, both analogue and digital, to produce design elements, providing students with a wider range of tools and methods to explore.

Losses

Despite the new possibilities, the Covid-19 pandemic has also led to several losses in architectural design education. For instance, the increased amount of work for instructors and students has been a major challenge. With remote learning, instructors have had to adapt to new teaching methods and technology while also providing rigorous assessments for their students. Additionally, students have had to adapt to new methods of learning and collaboration, which can be challenging and time-consuming. The mixing between the home environment and the classroom environment has also led to several difficulties. The home environment may not be conducive to learning and can be distracting, while the classroom environment may no longer be accessible to students, resulting in a loss of community and peer support.

In terms of design critiques, technical limitations and problems on both sides have led to the loss of critique dynamics. Online critiques may lack the same level of engagement and interaction as in-person critiques, which can impact the quality of feedback and design outcomes. The virtual setting can also be tiring for instructors and students, as it requires a particular type of attention and can lead to fatigue. Finally, in external forms of representation, difficulties in drawing on the computer and understanding aspects of representations such as scale and proportion have been observed. The accentuation of the role of the image at the expense of space has also been a challenge, which was already a trend in architectural design education before the pandemic.

Opportunities

Opportunities are mainly associated with the external forms of representation. The greatest opportunity seems to be related to the so-called traditional forms of representation, such as hand drawing or sketching and physical models. Instead of being forgotten, these forms of representation gained a new use and potential when combined with digital media. In fact, the need for online teaching seems to have underlined the particular importance of hand drawing or sketching and its potential for wider use, both in the student's individual productions and in the interaction with the instructor during design critiques—so, as a didactic tool. In general, it is possible to understand the present circumstance, determined by the consequences of the pandemic emergency, as an opportunity in itself. An opportunity

for research and experimentation on the different approaches to architectural design teaching, in this case, focusing on the role of external representations.

Threats

The set of new possibilities and losses revealed during this period seem to indicate that distance education tends to accentuate inequalities between students, both in terms of performance and from a socio-cultural point of view. Students with the most difficulties were the ones most affected by the pandemic—on the one hand, due to new requests placed on them, on the other hand, due to the difficulty of instructors in following their progress. The socio-economic inequalities of the students were also evident. It seems important not to lose the social dimension of teaching. One of the issues has to do with sharing, with contact, with knowledge of the colleagues' work, with the establishment of links with instructors, with the classroom environment. Moreover, when referring to the positive results of distance education, it is necessary to bear in mind that when the non-presential regime was adopted, it was preceded by a semester of classes in presence or in a mixed modality. According to some instructors, this initial period was essential for the organization of classes, especially for students of the first years, considering their lack of experience and autonomy.

Adaptive design studio

The Covid-19 pandemic has disrupted the traditional way of teaching architecture and has forced educators to adapt to new technologies and modes of instruction. This shift has led to both opportunities and challenges in the organization of design studios, design critiques, and external forms of representation.

In terms of new possibilities, the use of virtual classrooms has allowed for greater articulation between courses and the inclusion of guests from different geographies, increasing the diversity of perspectives available to students. The sharing of content and work on a collective drive has also enabled instructors and students to access materials and collaborate more easily. During design critiques, the direct participation of the whole class and the ability to open a browser to show a reference design or constructive detail have facilitated communication and enhanced the learning experience.

However, there have also been losses associated with the pandemic's impact on design education. These include an increased workload for both students and instructors, difficulties in rigorous assessments of student work, and the mixing of the home environment and classroom environment. Technical limitations during critiques and the tiring nature of online interactions have also impacted the dynamic of critiques, making it

more challenging for instructors and students to make themselves understood. The emphasis on digital forms of representation has also led to difficulties in understanding aspects of representations such as scale and proportion.

Despite these challenges, the pandemic has presented opportunities for investigating and experimenting with different approaches to architectural design teaching. The use of traditional forms of representation, such as hand drawing and physical models, has gained new relevance and potential when combined with digital media. The importance of hand drawing as a didactic tool and the potential of physical models for communication have become more evident. However, the pandemic has also highlighted socio-economic inequalities among students, which may be accentuated by distance education. Therefore, it is important not to lose sight of the social dimension of teaching and to ensure that students have equal access to resources and opportunities.

5.5 Drawing as a historical record

5.5.1 Outline

In this section, we will examine a set of thesis drawings produced by former students of MIT between 1873 and 1968, which are archived at the institution. Our goal is to recognize how the significance of drawing has evolved over time. To do this, we will compare this set of thesis drawings with the course catalogs of the corresponding year, to understand the relationship between representation and teaching approach. Our study begins with an introduction to the history of MIT, the establishment of the architecture course by Robert Ware, and the strategy of storing these drawings as a teaching tool.

Then, we will analyze the archive material, where we will combine the thesis drawings with the course catalogs, as well as some of the main events that directly or indirectly affected the institution. The interpretation of this material will allow us to determine the process of transforming the teaching of architecture at MIT, especially regarding the relationship between forms of representation and the teaching model, and the different roles that drawing has assumed over time.

The methodology employed for data collection and analysis in this section focused on an archive study. The MIT Museum archive contains 7293 thesis drawing entries from 1586 students, systematically archived between 1873 and 1968. However, a significant portion of this collection is either unavailable for consultation or not digitized, leaving only 413 entries available for our study. Therefore, we selected 145 entries from this set, seeking to cover both the diversity of representations and their distribution over the years, which as we will see, is quite asymmetric.

In association with the students' thesis drawings, we also analyzed the course catalogs published by the institution every year, presenting the school's general guidelines, different courses, curriculum, and subject plans. We selected 19 catalogs, representing one catalog every five years, to analyze the evidence. To analyze the evidence, we needed to use two tools: a database to compile the information and metadata (see Appendix 3), similar to what we did before, but also a visual timeline to organize the drawings and catalogs chronologically (figure 49). Using these two tools for analysis allowed us to process both written and visual evidence simultaneously.

5.5.2 Findings

Historical background

The Department of Architecture at MIT is recognized as the oldest architecture program in the United States, having been founded in 1865 by William Robert Ware. Ware was not only a renowned architect but also an architecture educator, having designed Harvard Hall and later establishing the architecture program at Columbia University based on his MIT model. To create the architecture program at MIT, Ware undertook an extensive study of European architectural programs, visiting various academic institutions and architects in France, England, and Germany. He drew inspiration from the Fine Arts School in Paris, which was renowned for its technical orientation, focus on applied sciences, and teaching of architectural design (Block 2019).

Ware's curriculum for the architecture program at MIT was science-based and divided into two areas: construction-practice and composition-design. However, he still identified architecture as a branch of the Fine Arts and sought a balance between science and the artistic dimension (Ware 1866). He believed that drawing and manual skill were crucial components of architectural education, and students were expected to have rigorous training in mechanical and freehand drawing, including instruction in sketching in black and white and watercolor, as well as drawing from both casts and life (Ware 1866).

To support this part of the students' education, Ware collected an extensive collection of drawings, prints, photographs, models, and casts, which were deposited in the Museum of Fine Arts in Boston, allowing students free access to these visual resources. Ware also placed great emphasis on student work, collecting and archiving the best examples of drawings and design projects produced by students, which were hung on the studio walls until they were replaced by the work of subsequent years' students.

This practice of collecting student work continued for nearly a hundred years until the late 1960s, when individual property and creative rights issues were raised. Despite attempts by students to revise this policy and bring back the practice, it ultimately failed (Kimberly 1996).

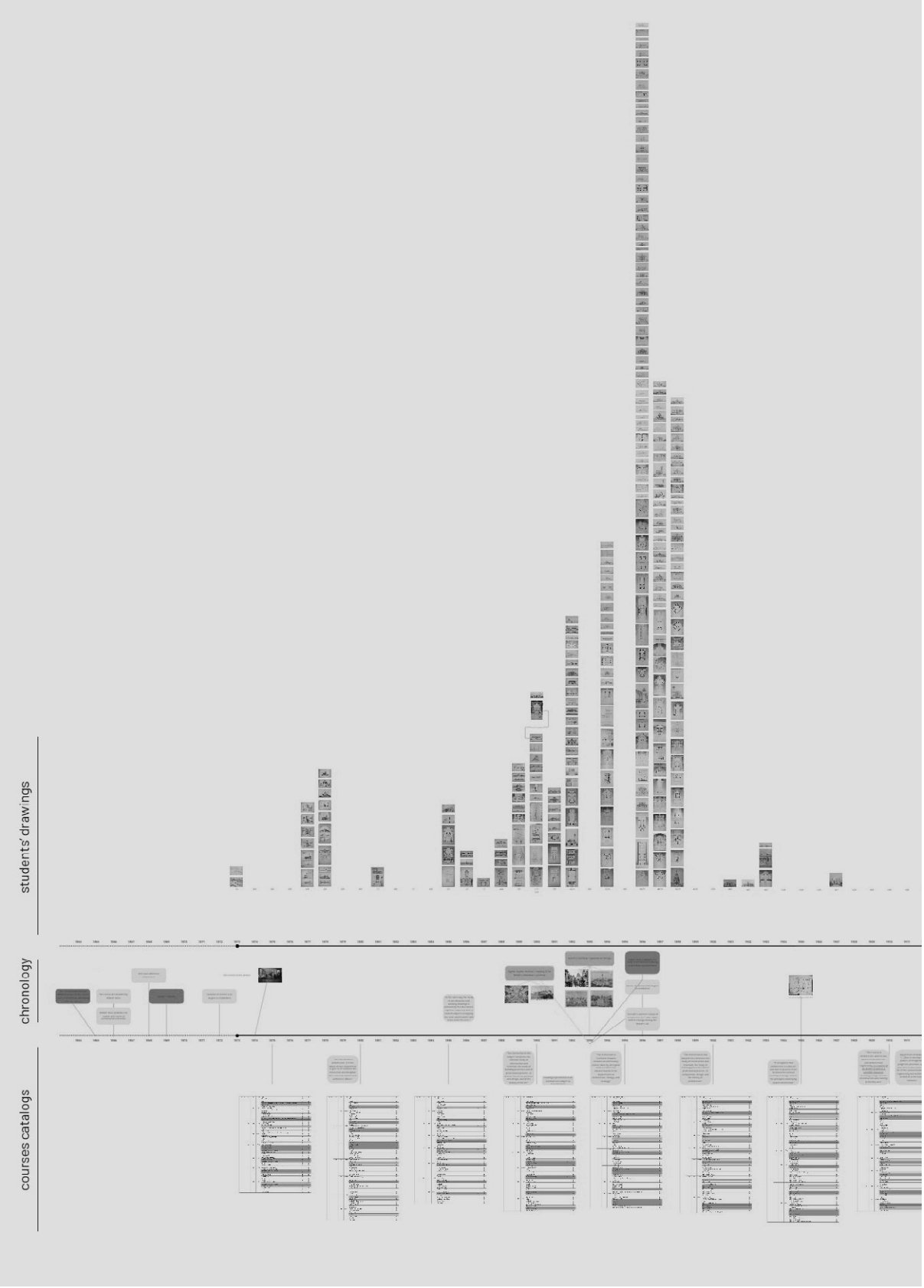
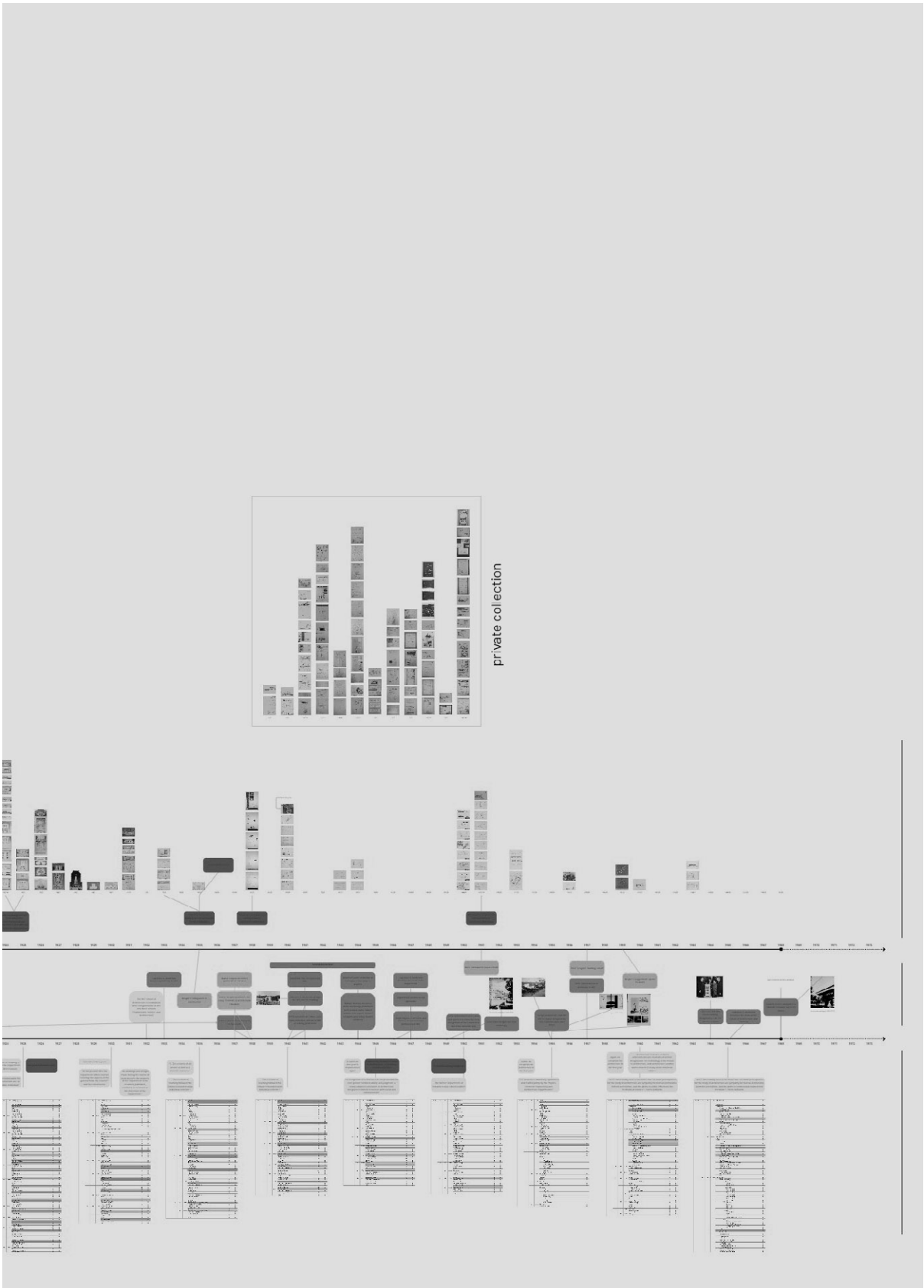


Figure 49. Visual timeline. The top band displays the thesis drawings selected for analysis, the middle band highlights significant historical events related to the school and others referenced in the literature, and the bottom band presents course catalogs synthesized into curricular programs, with courses related to representation emphasized


private collection

However, the student drawings and projects produced during this time remain a valuable source for mapping the department's evolution, illustrating both what was intended for MIT students to observe and appreciate and the changing architectural trends that arrived at the school, especially the advent of modernism.

Data analysis

This study primarily relied on the MIT Museum, where the student thesis drawings are archived, and the MIT Libraries Dome, which stores the course catalogs. The period analyzed spans from 1873 to 1968, defined by the first and last entries in the *Student Thesis Drawings Collection*. The collection includes 7,293 entries with associated metadata. This metadata serves as a valuable source of complementary insights, such as the increasing number of architecture graduates and the growing student-to-drawing ratio over time (figure 50).

Despite the size of the collection, only a small portion has been digitized, totaling 413 entries unevenly distributed over the years. After an initial overview, it was necessary to narrow the sample for a more detailed analysis. A criterion was established to select up to five drawings per year, prioritizing works from different students. This resulted in a final sample of 145 thesis drawings, which were examined for panel organization and content, modes of representation, architectural language, and functional programs.

In parallel, course catalogs published annually during the study period were reviewed. These catalogs, archived at the MIT Libraries Dome, outline the institution's general policies, available courses, curricula, and subject plans. Due to the length of these documents, ranging from 60 to 300 pages, one catalog was analyzed every five years, yielding a total of 19 catalogs. The analysis focused on course descriptions, curriculum structure, and details of drawing and representation subjects.

The aim was to systematically analyze these archival materials and correlate them with MIT's historical timeline through a data-driven approach. A mixed-methods framework was adopted, combining qualitative analysis of the drawings and catalogs with quantitative data.

The workflow was divided into three phases. The first phase involved systematically collecting, organizing, and processing archival materials and metadata to establish a dataset. The second phase was iterative, testing and refining analytical methods. Challenges in simultaneously analyzing the visual evidence of the drawings alongside the course catalogs led to the development of a visualization tool, referred to as a *visual timeline* (figure 49).

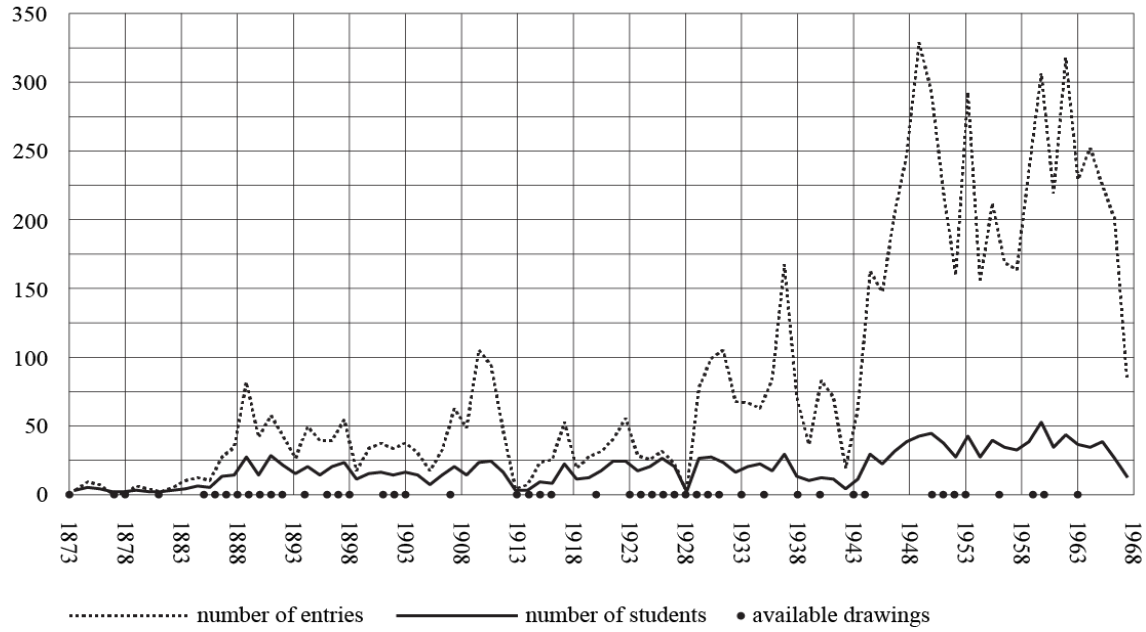


Figure 50. Relationship between the number of thesis drawings entries in the archive, the number of students, and the available materials

The *visual timeline* allowed for the identification of trends in the chronology of the thesis drawings, verifying the consistency of panel compositions, representation modalities, and architectural languages (figure 51). Based on this analysis, four distinct periods were defined: the first from 1873 to 1885, the second from 1885 to 1924, the third from 1924 to 1933, and the fourth from 1933 to 1968, through which the results were organized. In the final phase, the focus shifted to interpreting the results.

This involved conducting a narrative literature review on the institution's history, with particular attention to the Architecture course program. This step was especially relevant as it provided a foundation for the collected and analyzed data, allowing for its contextualization within the history of MIT and the teaching of architecture in the United States.

arch_marker	elements	type	num_elements	captions	rendering	filled_back	background	constructive	line
1874.T.001	multiple	elevation, section, plan	4	y	real	n	real	n	hard
1877.T.003	multiple	elevation, plan	3	y	real	y	abstract	n	hard
1877.T.004	multiple	elevation, section, plan, perspective	5	y	real	y	real	n	hard
1877.T.005	multiple	elevation, plan, detail	5	y	real	y	abstract	n	hard
1878.T.001	single	perspective	1	n	real	y	real	n	hard
1878.T.003	multiple	elevation, section, plan	6	y	real	y	abstract	n	hard
1878.T.005	multiple	elevation, plan, detail	4	y	real	y	abstract	n	hard
1881.T.001	multiple	elevation, section, plan, detail	9	y	real	y	abstract	y	hard
1885.T.001	single	elevation	1	y	real	y	abstract	n	hard
1885.T.002	single	section	1	n	n	y	n	n	hard
1885.T.003	single	plan	1	y	n	y	n	n	hard
1886.T.001	single	elevation	1	y	real	y	abstract	n	hard
1886.T.002	single	plan	1	y	n	y	n	n	hard
1887.T.001	multiple	elevation, plan	2	y	real	y	abstract	n	hard
1888.T.001	multiple	elevation, section	2	n	real	y	real	n	hard
1888.T.002	multiple	plan	4	y	n	y	abstract	n	hard
1888.T.003	multiple	elevation, section	2	y	real	y	abstract	n	hard
1889.T.001	multiple	elevation, section, plan	6	y	real	y	abstract	n	hard
1889.T.004	multiple	section, plan	3	n	real	y	abstract	n	hard
1889.T.007	multiple	elevation, section	2	y	real	n	real	n	hard
1890.T.001	single	section	1	y	n	n	n	y	hard
1890.T.005	multiple	elevation, section	2	y	real	y	real	n	hard
1890.T.006	single	plan	1	n	real	y	real	n	hard
1890.T.009	single	perspective	1	n	real	y	real	n	hard
1891.T.001	single	elevation	1	y	real	n	real	n	hard
1891.T.006	single	elevation	1	n	real	n	abstract	n	hard
1891.T.007	single	plan	1	n	real	y	abstract	n	hard
1891.T.009	single	elevation	1	n	real	n	abstract	n	hard
1891.T.010	single	section	1	y	real	n	abstract	n	hard
1892.T.002	single	elevation	1	n	real	y	abstract	n	hard
1892.T.005	multiple	plan	3	y	real	y	abstract	n	hard
1892.T.006	multiple	elevation, section	2	y	real	y	abstract	n	hard
1892.T.009	multiple	elevation, section	2	n	real	y	abstract	n	hard
1892.T.012	multiple	elevation, section	2	n	real	y	abstract	n	hard
1892.T.013	multiple	plan	4	y	real	y	abstract	n	hard
1894.T.001	single	elevation	1	n	real	y	abstract	n	hard
1894.T.002	single	plan	1	n	real	y	abstract	n	hard
1894.T.003	single	section	1	n	real	y	abstract	n	hard
1894.T.007	single	section	1	n	real	n	real	n	hard
1894.T.018	single	elevation	1	n	real	y	abstract	n	hard
1894.T.018.0	single	section	1	n	real	y	abstract	n	hard
1896.T.001	single	plan	1	n	real	y	real	n	hard
1896.T.002	single	plan	1	y	real	y	real	n	hard
1896.T.004	single	frontal	1	n	real	y	real	n	hard
1896.T.007	single	frontal	1	n	real	y	abstract	n	hard
1896.T.012	single	plan	1	n	real	y	abstract	n	hard
1896.T.052	single	frontal	1	n	real	n	real	n	hard
1897.T.001	single	frontal	1	n	real	y	real	n	hard
1897.T.004	single	plan	1	n	real	y	real	n	hard
1897.T.005	single	plan	1	n	real	y	real	n	hard
1897.T.006	single	section	1	n	real	y	abstract	n	hard
1897.T.018	single	elevation	1	n	real	n	real	n	hard
1897.T.025	single	plan	1	n	real	n	real	n	hard
1898.T.001	single	elevation	1	n	real	y	abstract	n	hard
1898.T.002	single	plan	1	n	real	y	abstract	n	hard
1898.T.004	single	frontal	1	n	real	y	abstract	n	hard
1898.T.014	single	plan	1	n	real	y	abstract	n	hard
1901.T.001	single	frontal	1	n	real	y	real	n	hard
1902.T.032	single	frontal	1	y	real	n	abstract	n	hard
1903.T.009	single	frontal	1	n	real	y	real	n	hard
1903.T.010	single	elevation	1	n	real	y	real	n	hard
1907.T.030	single	frontal	1	n	real	y	real	n	hard
1913.T.023	multiple	section	2	n	n	y	real	n	hard

Figure 51. Detail of the dataset with analysis categories

First period – 1885-1924

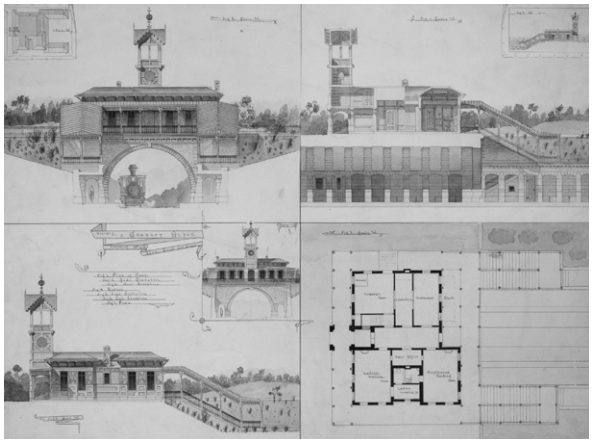
The first period of architectural drawings had limited archival material but was distinct from later periods due to the slower evolution of its architectural language, panel composition, and representation style.

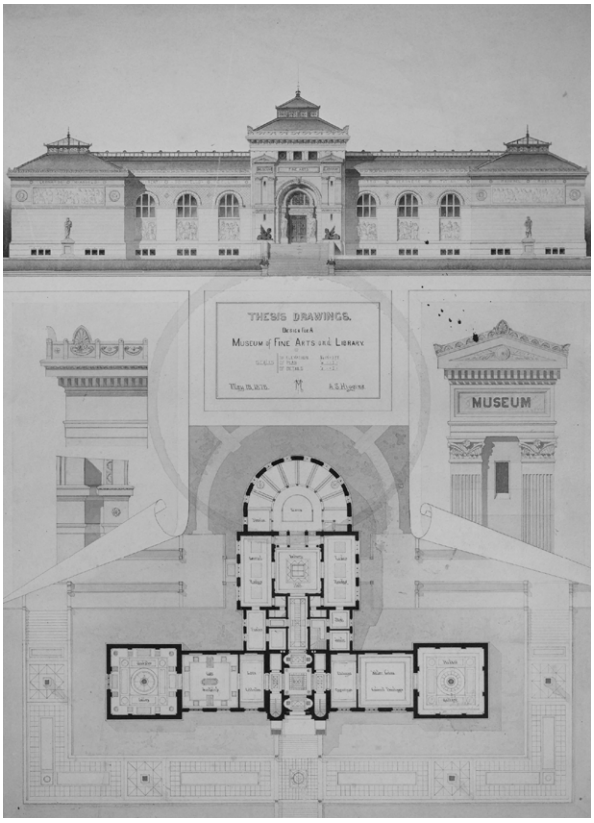
A total of eight drawings were analyzed. The panels provided significant design information, featuring an average of four elements per panel. Elevations and plans were the most frequent (n=7 each), followed by sections (n=4), architectural and construction details (n=3), and perspectives (n=2). Compared to later periods, this period's panels contain a higher percentage of construction details and elements, making them more informative.

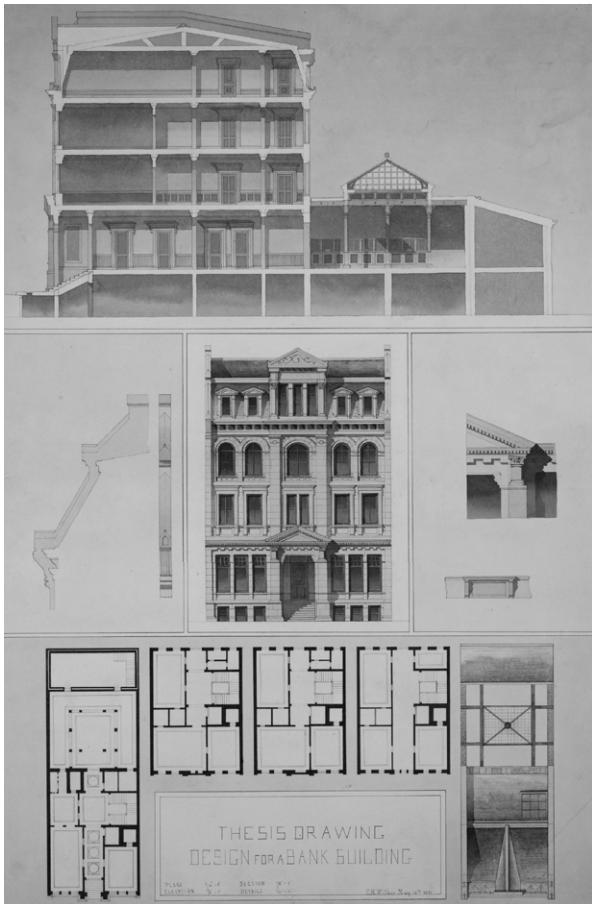
In terms of representation, elevations, sections, details, and perspectives were rendered, but plans were not. The renderings were realistic, with abstract scenarios (n=5) being more common than real scenarios (n=3). All drawings featured hard lines and were complemented by watercolors to depict color, light, and shadow. While construction details were included, most drawings prioritized the presentation of the project rather than construction specifics. Architecturally, this period was characterized by Revivalism, Neo-Renaissance, and Neoclassical styles, which continued into the second period.

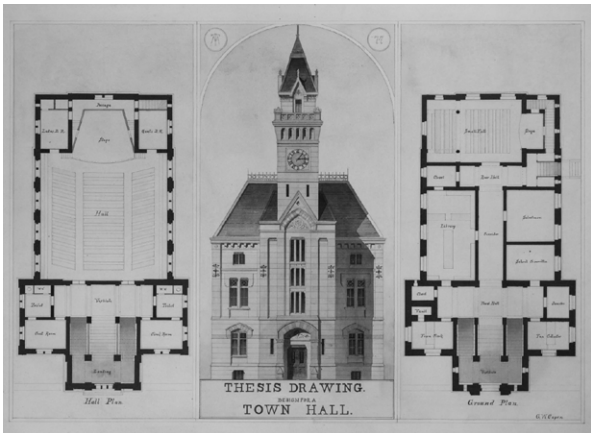
During this time, the curriculum required an average of seventy-two courses, with fifteen focused on representation, including *Freehand Drawing*, *Shades and Shadows*, *Mechanical Drawing*, *Perspective*, and *Blackboard Drawing*. These representation courses constituted about 20% of the curriculum.

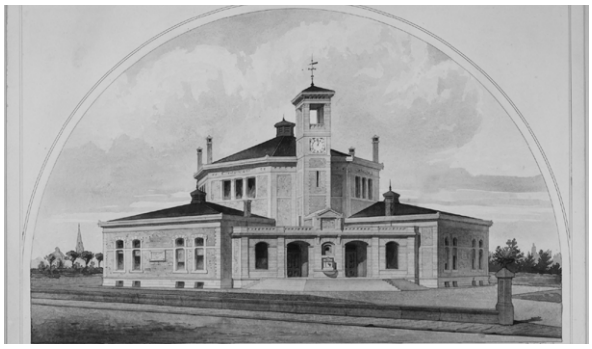
The curriculum spanned four years and eight semesters, with the first two semesters being common across all subjects. Students were required to take two key representation courses, *Mechanical Drawing and Elements of Descriptive Geometry and Perspective*, alongside *Freehand Drawing*. By 1869-1870, the Architectural Museum had assembled a significant collection of photographs, prints, drawings, and casts, underscoring the importance of representation in architectural education.











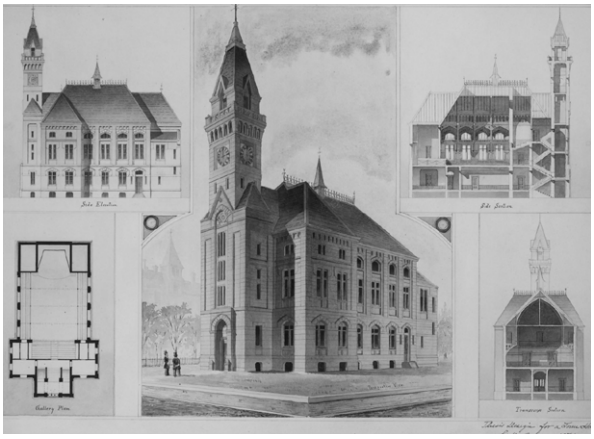


Figure 52. Selection of drawings by students from the first period

Second period – 1885-1924

This period was characterized by consistency in panels, representation, and architectural language, displaying significant homogeneity and longevity. A total of 73 drawings were analyzed. Panels became less informative, focusing more on panel composition and the quality of representation. Single-element panels (n=53) predominated over multiple-element panels (n=20), with captions becoming less common.

Plans (n=24) and elevations (n=23) continued to predominate, while the perspective elevation (n=17) emerged as a new element. Sections (n=21) followed, with perspectives (n=2) and details (n=1) practically disappearing. An interior perspective appeared for the first time. Representations focused on rendering all elements, including plans, with realistic renderings dominating.

Architectural styles of this period leaned toward Revivalist trends, including Neogothic, Neo-Renaissance, Neoclassical, and some eclectic architecture. Cultural facilities (n=16) were the most common program, followed by religious facilities (n=10) and private housing (n=9). Most cultural and educational buildings, along with housing, were concentrated between 1885 and 1910.

The constructive dimension was almost nonexistent, with only one example of a technical-constructive drawing. Watercolors complemented hard lines in representation, particularly in depicting natural scenarios. Panel compositions became more centered and symmetrical, often resembling paintings and typically featuring a single element.

During this period, an average of seventy-two mandatory courses were required, with eighteen related to representation, including *Freehand Drawing*, *Pencil Sketching*, *Charcoal Sketching*, *Pen and Ink*, *Watercolors*, and *Modeling*. These courses constituted around 25% of the curriculum, marking an increase compared to the previous period.

By 1920, the course expanded to twelve semesters. Architecture became the only program with a non-common first semester, distinguished by *Freehand Drawing* and *Drawing and Descriptive Geometry*, making freehand drawing instruction exclusive to architecture for the first time. Optional courses from 1900 and 1905 catalogs showed that 39% of courses were mandatory, with approximately 28% related to representation. By 1985, freehand drawing was included in elementary courses for all students, with advanced coursework available in Architecture, Biology, and Geology.

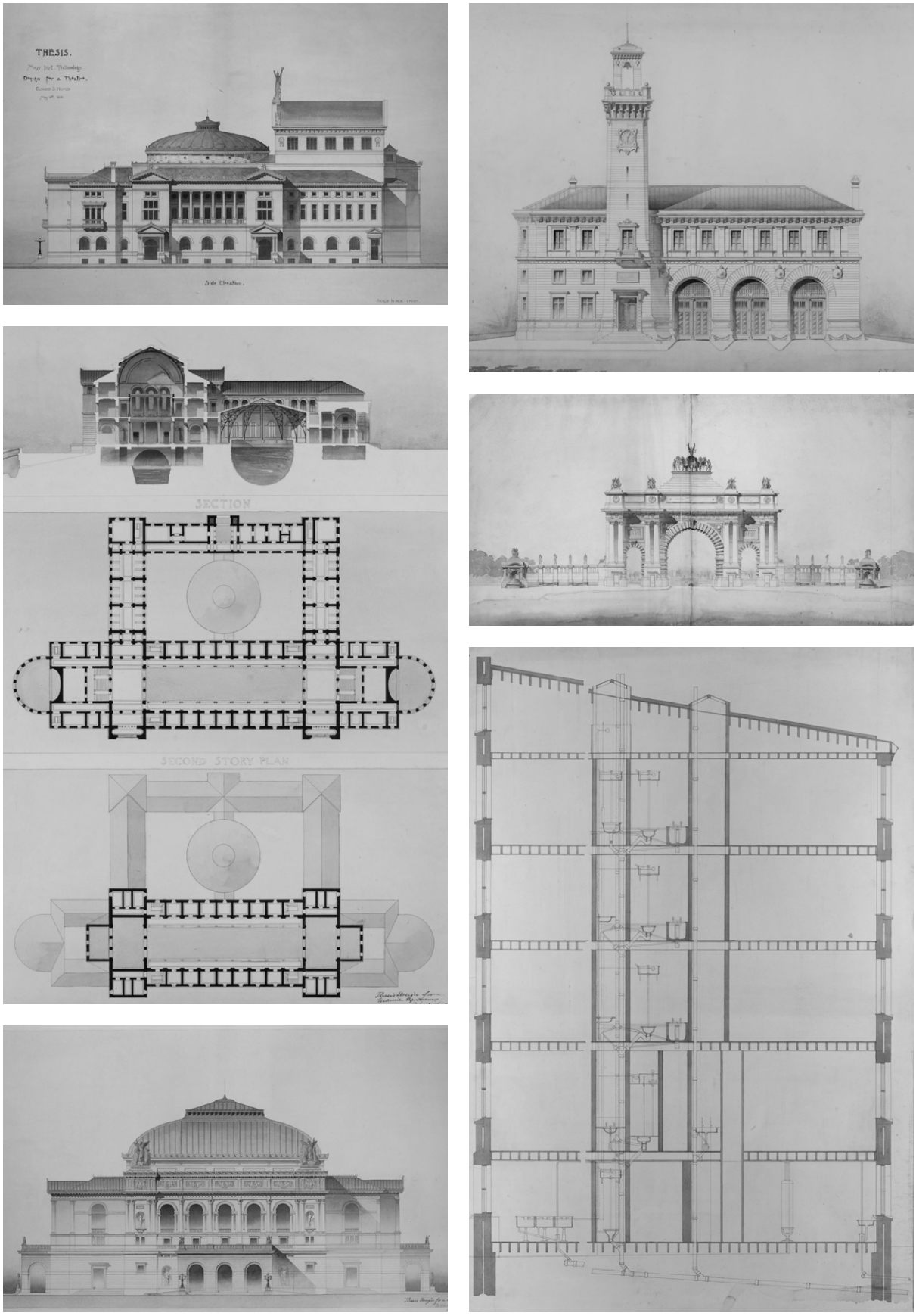


Figure 53. Selection of drawings by students from the second period

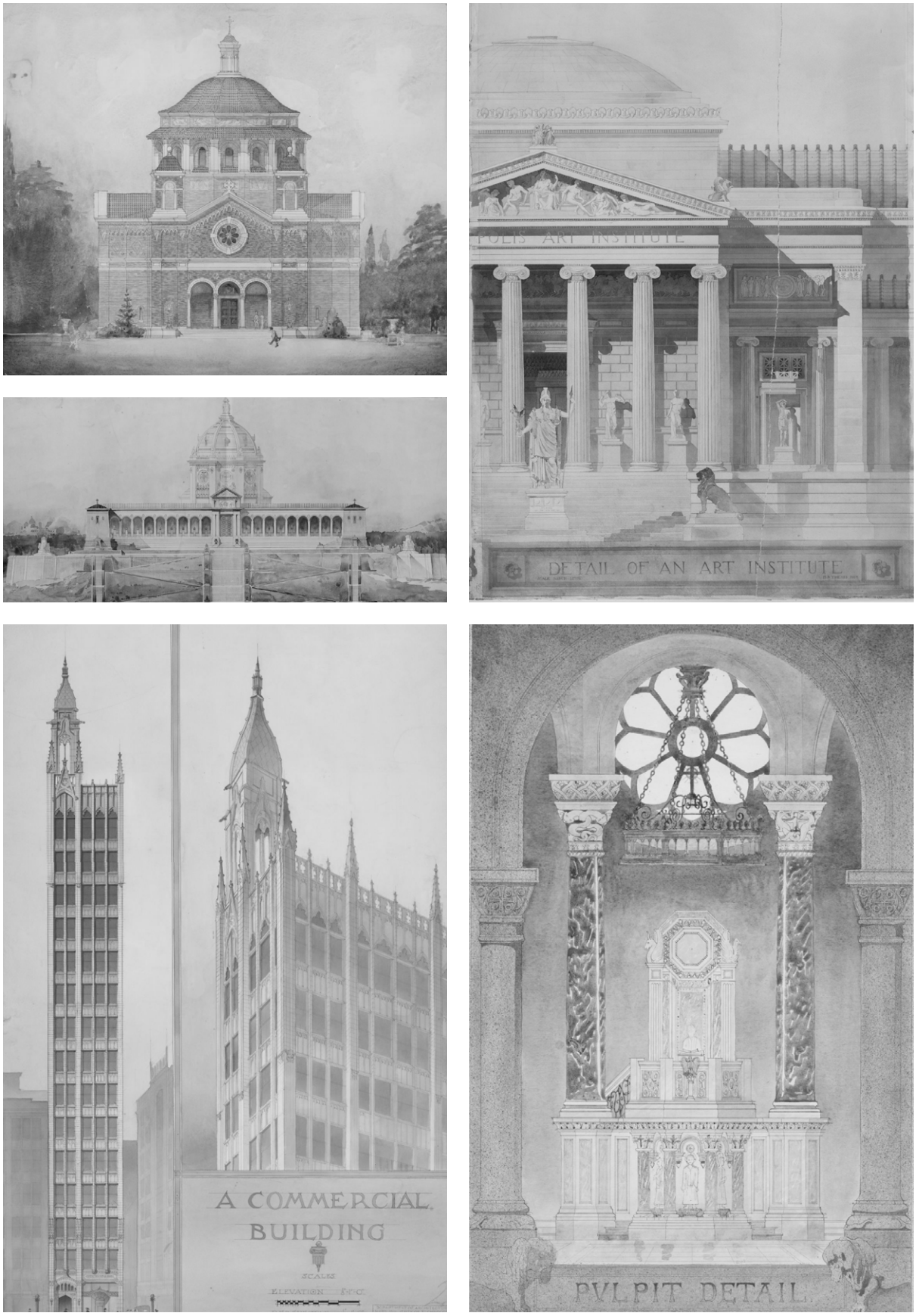


Figure 54. Selection of drawings by students from the second period

Third period – 1924-1933

This period represented a transition from established trends to the modern movement, with a total of 19 drawings analyzed. Panels became more informative, with a slight predominance of multiple-element panels (n=11) over single-element ones (n=9), averaging two drawings per panel. Captions resurfaced, and some panels included blocks of text. Perspectival elevations (n=12) dominated, followed by sections (n=11), plans (n=10), and elevations (n=5). Flat representations remained prevalent, with no perspectives or details included.

Realistic renderings in real environments (n=15) were predominant over abstract settings (n=3). Urban contexts increased in frequency over natural ones. Atmospheric effects, such as the use of light to add drama, became a defining feature. All drawings continued to use hard lines, supplemented by watercolors and other mediums.

Liberty-style buildings marked a departure from revivalist and eclectic trends. This style accompanied new design programs, including large automobile workshops, shopping centers, office towers, and cinemas. Commercial programs (n=6) and public services (n=4), particularly post offices, stood out.

The curriculum during this period averaged ninety courses, with seventeen focused on representation, including *Freehand Drawing*, *Perspective*, *Shades and Shadows*, *Watercolors*, and *Modeling*, accounting for 18% of the total curriculum—a reduction compared to the previous period.

The curriculum changed from 14 years and 12 semesters to 5 years and 10 semesters, a structure that remained in place until the end of the period under consideration. The architecture course was the only one with a separate first semester, which included freehand drawing. By 1925, the Drawing Division was integrated into the architecture department, and the *Watercolors* course was offered for the last time.

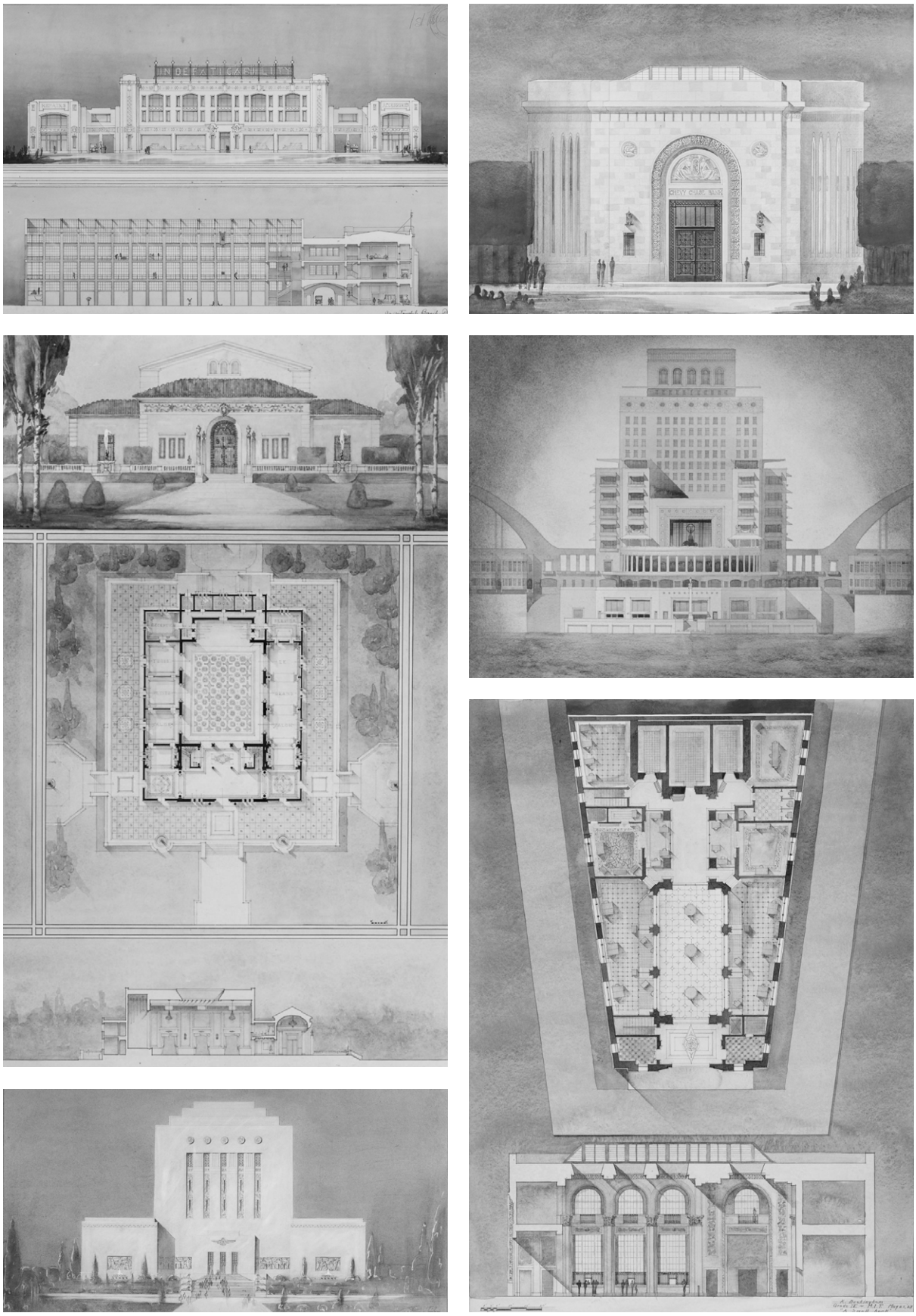


Figure 55. Selection of drawings by students from the third period

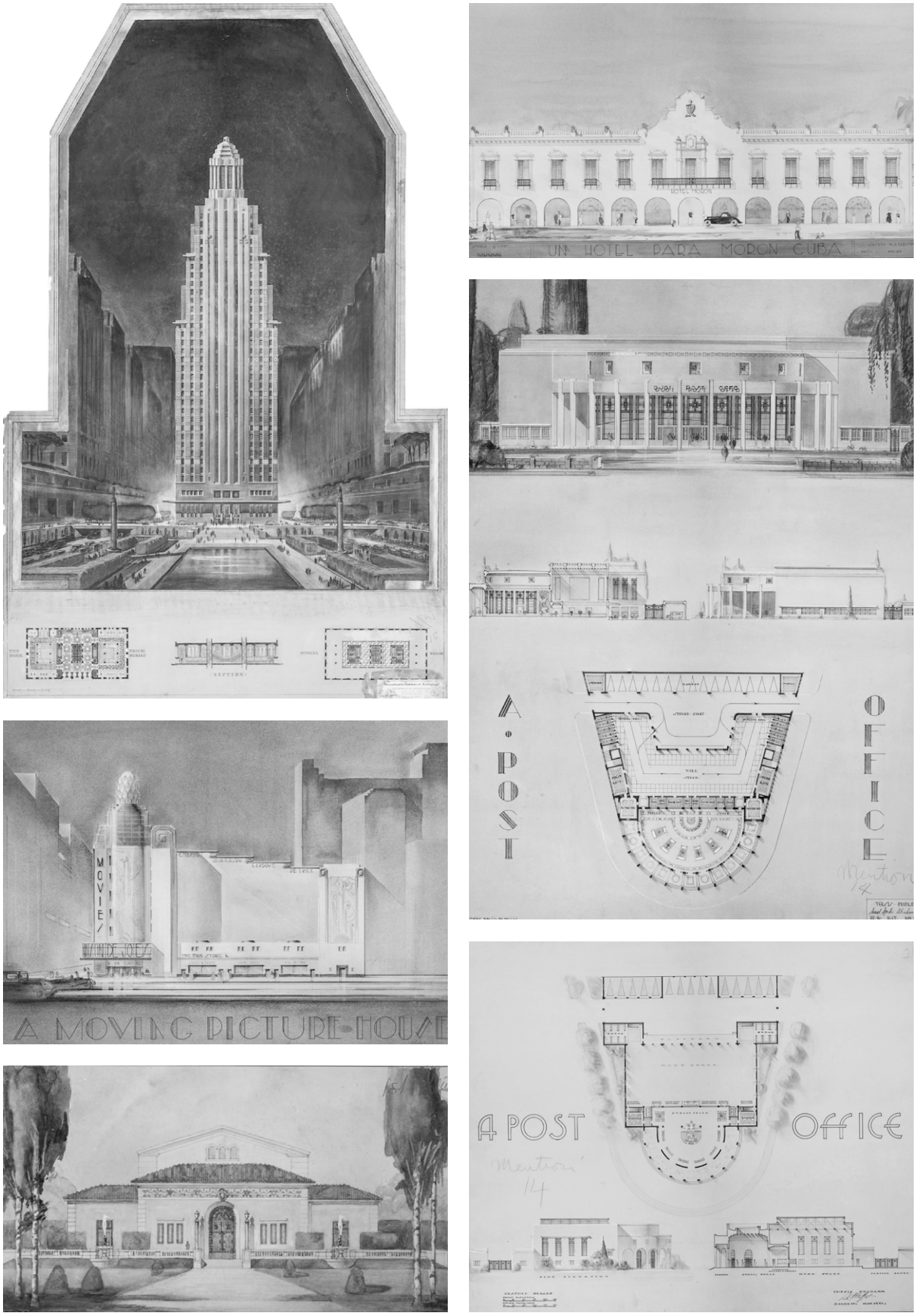


Figure 56. Selection of drawings by students from the third period

Fourth period – 1933-1968

The fourth period marked the most significant and rapid transformation of the analyzed timeframe. A total of 45 drawings were considered. Panels became highly informative, with many multiple-element panels (n=27) exceeding single-element ones (n=18), averaging four elements per panel and occasionally surpassing seven. Panel labeling became standard, accompanied by blocks of text and a diverse arrangement of elements.

This period featured the most diverse range of represented elements. In addition to plans (n=24), elevations (n=12), and sections (n=5), perspectives grew (n=6) and details reappeared (n=6). New elements emerged, including sketches (n=4), photography and collage (n=2), maps (n=2), and perspective construction sections (n=2). Site analyses and organigrams appeared for the first time.

Representation was mostly hardline (n=40), with freehand elements (n=5) making their first appearance. Renderings were limited to elevations and perspectives, with a stylized approach replacing realism. Interior and furniture representations became more common. Constructive aspects gained importance, as constructive details and technology were integrated into architectural drawings. Modernist architectural language dominated, with a focus on private service programs (n=20), educational and religious facilities (n=7 each), and industrial buildings (n=6).

During this period, an average of fifty-six mandatory courses were offered, with six related to representation, including *Graphics*, *Graphic Presentation*, *Graphics Laboratory* (freehand drawing), and *Visual Fundamentals*. These courses represented nearly 9% of the total.

By 1950, the Department of Drawing was renamed Graphics and focused primarily on technical drawing, referred to as Engineering Drawing. By 1965, the curriculum was organized into distinct groups—*Visual Design*, *Architectural Design*, *Structures*, *Technology*, and *History*—a structure still in use today.

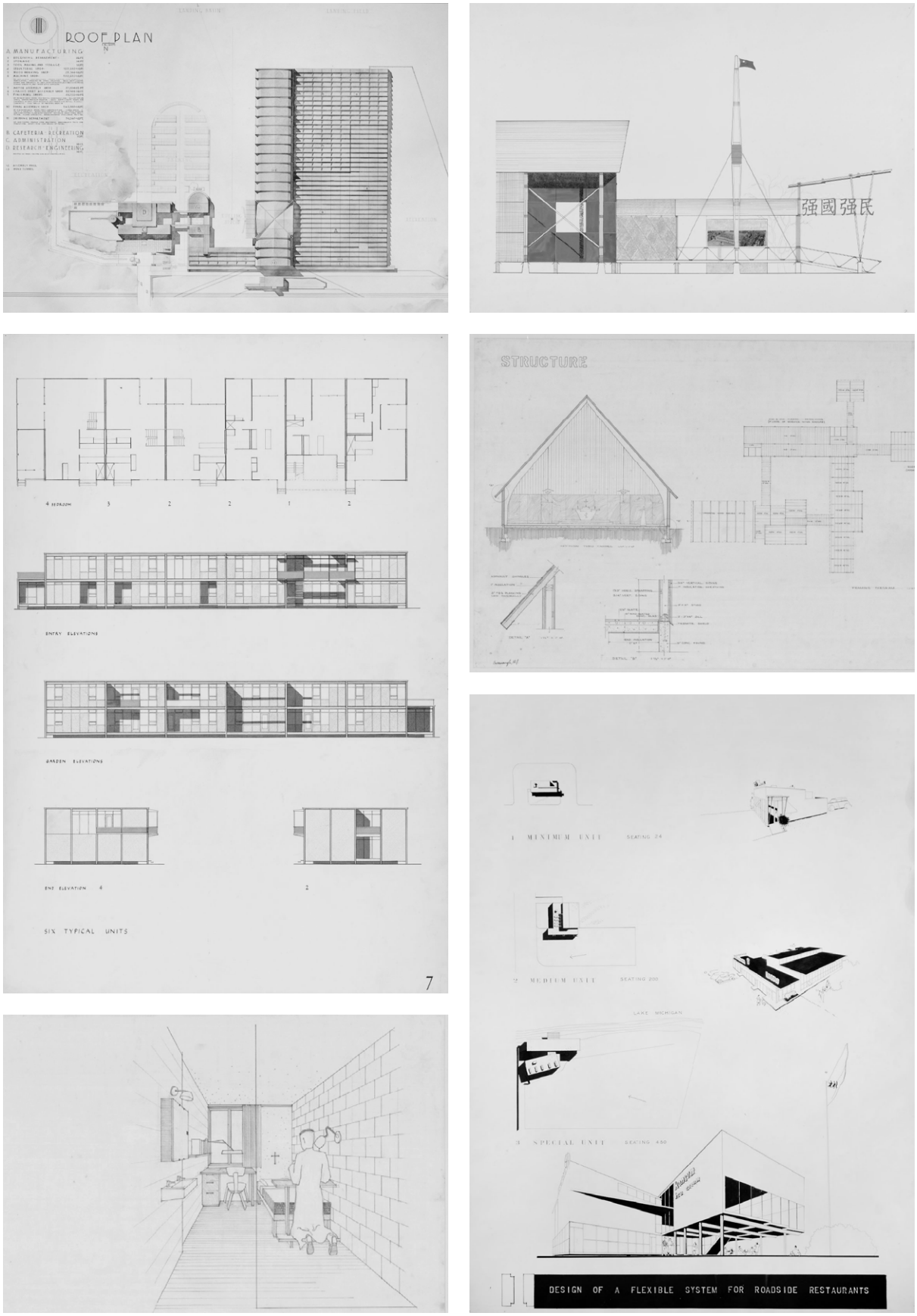


Figure 57. Selection of drawings by students from the forth period

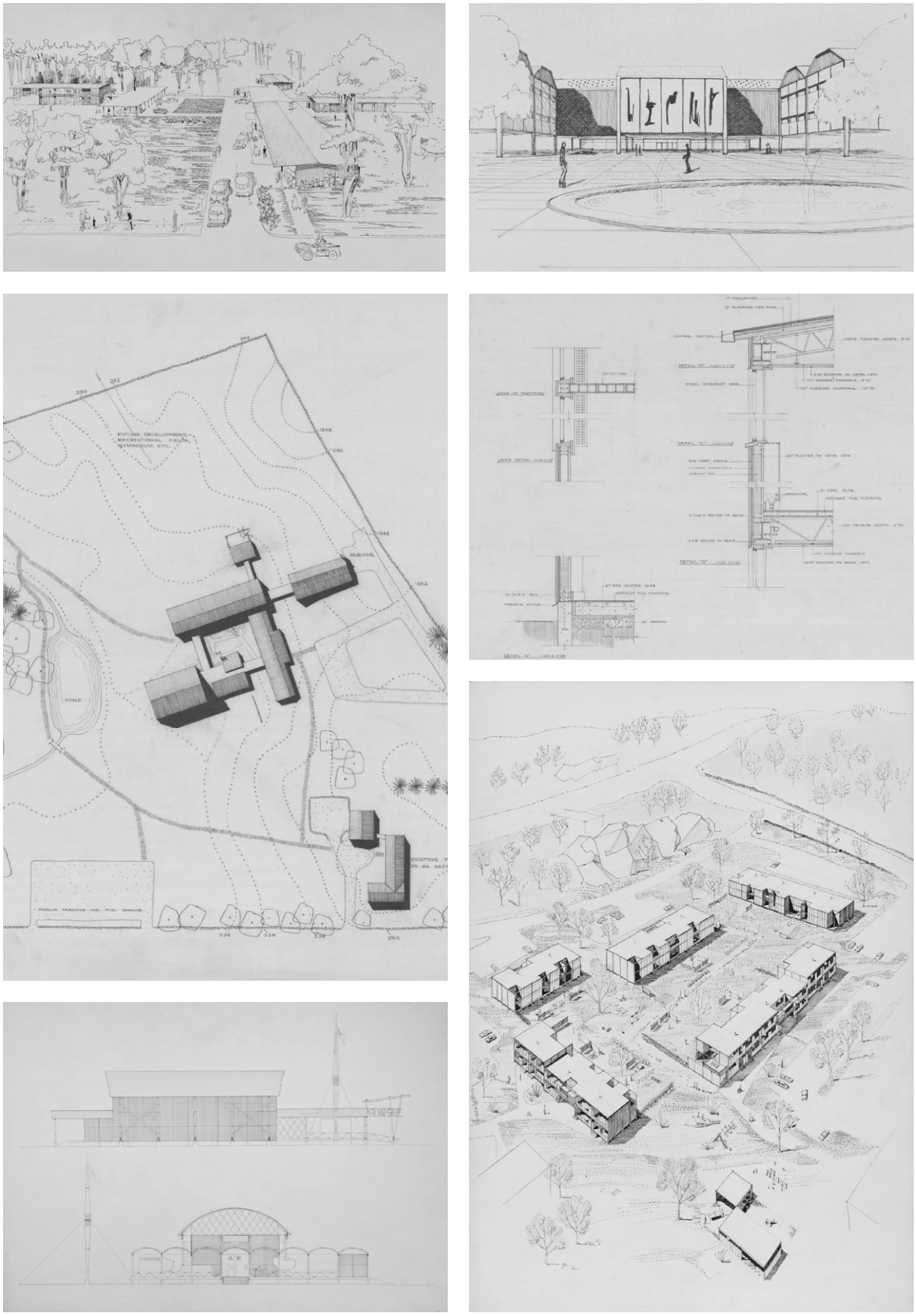


Figure 58. Selection of drawings by students from the forth period

5.5.3 Considerations

Trends and shifts

The time range under consideration spans from 1873 to 1968, which encompasses the founding of the architecture course in 1866 and its development until the post-war period. During this time, the institution established itself as an international school, which defined its identity and remains recognizable today.

Archival material, catalogs, and complementary bibliography suggest a set of constants and deviations during this period. Interestingly, the school's proposals are not always reflected in the students' work, particularly in the fourth period. While the first and second periods displayed authentic paintings with great qualities of rendering expressed through color, light, and shadow, there was scarce use of perspective. Panels with only one drawing, especially the perspective elevation, became more frequent in the third period.

This shift in representation does not fully align with the curriculum plans, which emphasize freehand drawing and learning perspective, at least in these thesis drawings. Despite the students' extensive training in various forms and systems of representation, their productions say little about what they have learned. All drawings are rendered, including sections and plans, yet the constructive dimension is almost absent. Captions are also reduced to the point of disappearing, enhancing the painting-like quality of the panels.

During the transition from the third period to the fourth, there was a notable change, and drawings regained their informative character. Various elements were placed on the panels, including diverse forms and representation systems, captions and text blocks, and the constructive dimension gained importance (figure 59). This shift could be attributed to the immense transformation in construction technology which occurred during this period.

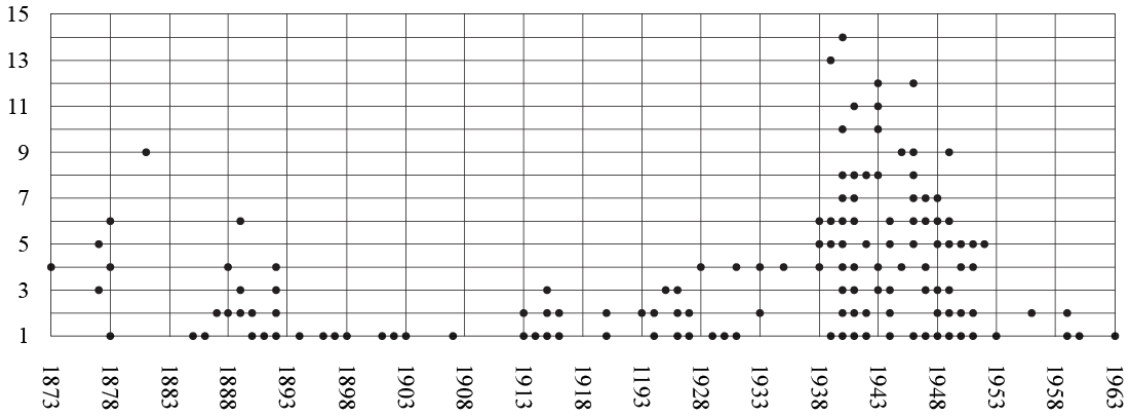


Figure 59. Number of elements per panel

The Neoclassical trend of architecture at that time, marked by the opening of the New Technology building in 1916, characterized the second period. In the first three periods, there was a general constant, whether in terms of representation, presentation of the project, architectural style and language, or programs. The fourth period was quite different, reflecting the trend of modern architecture in terms of design and representation, but without homogeneity. There was a diversity of paths and references, which was not seen in any of the previous periods. The school's openness to global references, the international influence of the modern movement, and the influx of guest instructors from diverse contexts probably contributed to this diversity.

The MIT campus's development after the Second World War, with projects for the Alvar Aalto New Dormitory (1949), the Kresge Auditorium and the MIT Chapel by Eero Saarinen (1955), the I. M. Pei Green Building (1964), and the Student Center by Eduardo Catalano (1968), was characterized by different understandings of architecture, diverse languages and approaches to design, and expressed this diversity, which seemed to influence the students.

The representation courses' significance is evident from the curriculum units. From the beginning of this time range, the representation courses exemplified a significant percentage of the total courses, peaking at 29 mandatory courses out of 98 in 1920, corresponding approximately to 30%. There was a progressive decline in the relevance of these courses until 1965, when there was not a single mandatory course, but five optional ones. However, this reduction in mandatory representation courses did not seem to decrease the quality of representations, which remained diverse and daring, especially towards the end of the fourth period. Interestingly, it is in the fourth period that the first sketches appear (figure 60).

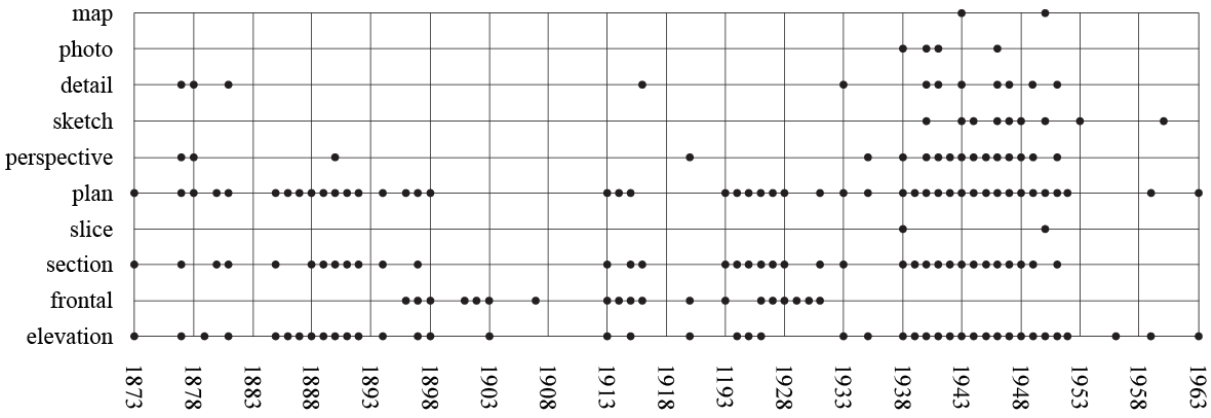


Figure 60. Types of elements in panels

The analysis also reveals other aspects that, unrelated to representation issues, allow us to understand how conceptions and areas of interest have changed historically. Looking at Figure 61, we see how the functional programs of the design projects change in each period. In the first and second periods, cultural programs were highly relevant, shifting to commercial and service programs in the third period, and, in the fourth, primarily focusing on housing and education.

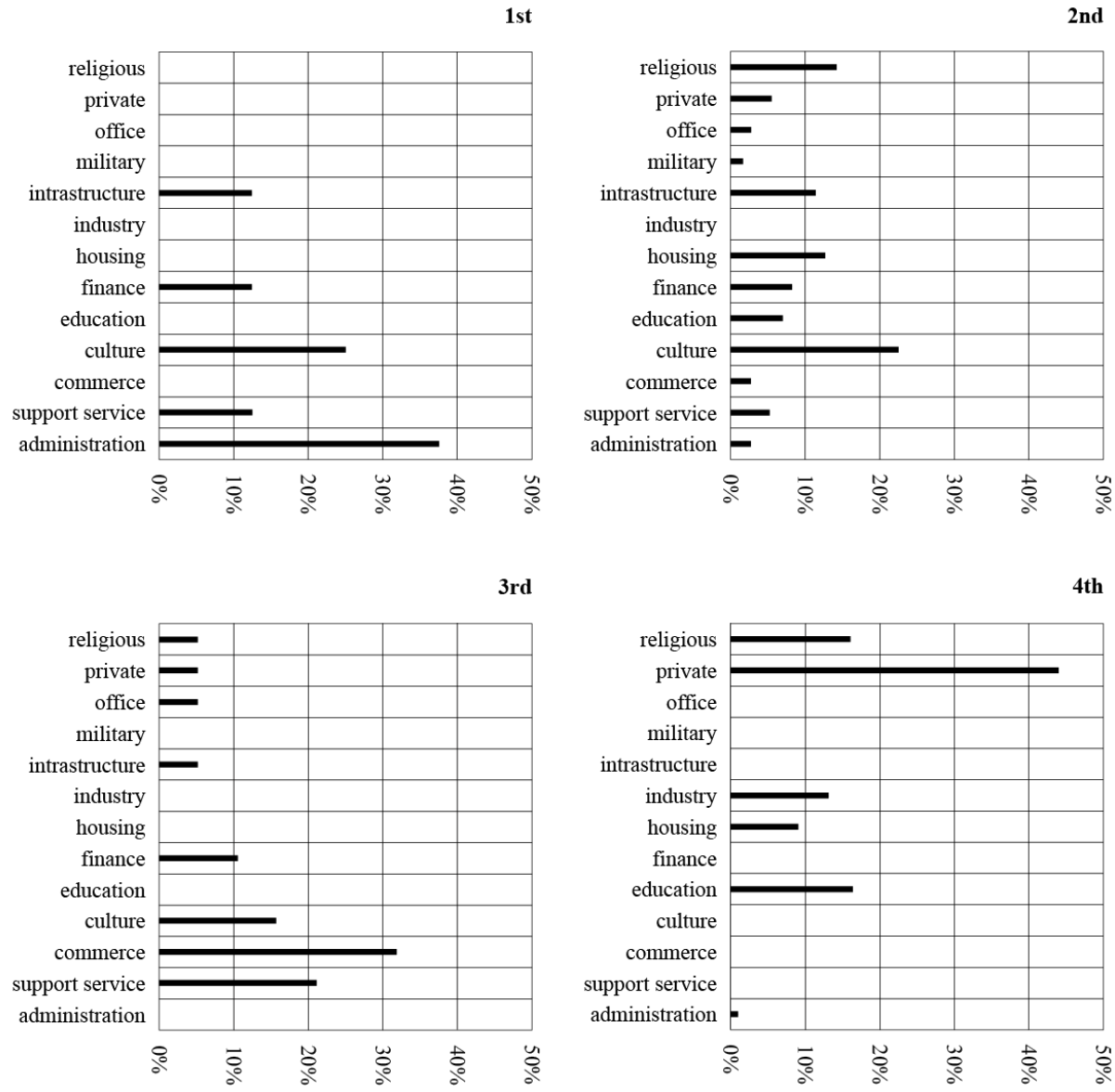


Figure 61. Functional programs of the thesis drawings in the four periods

Hardline and freehand

The MIT Department of Architecture has a long history of emphasizing drawing as an essential component of architectural education, as stated by Ware (in Kimberly 1996). From the department's inception to the post-war period, drawing served as both a work tool for students and a visual collection for pedagogical purposes. The archive of drawings that we are analyzing primarily consists of hardline drawings and renderings, which were the standard for thesis drawings. However, there are only a few freehand drawings from the fourth period, and no entries of other students' freehand drawings in the archive for this work. Despite this, we know from the course catalogs that freehand drawing was a mandatory course for students, with significant curricular weight.

As noted by Ware (1986), drawing in architecture is somewhere between the artist's and the engineer's work. Drawing is partially controlled by factual considerations, partially by the appearance of things, partially by geometric conditions, and partially by the draftsman's talent and judgment. Ware emphasizes the importance of starting with mathematical instruments to establish a standard of accuracy but then discontinuing their use as soon as possible to complete the work freehand.

According to Ware, the draftsman who was trained only as dividers and ruling pen is incapable of doing anything, while someone who learned to draw without them will have no difficulty doing so in any way. This seems a good metaphor for digital instruments, as without freehand drawing, the draftsman is just a mechanical draftsman.

Freehand drawing serves the design process but is then completed or finished in hardline drawing, as we can see in the thesis drawings in the archive. Two curious arguments justified the teaching of freehand drawing in this school, even in courses far removed from architecture or design. One of them is that freehand drawing is also used as a means of perception to train students and force them to closely observe reality. This is an essential aspect not only for architecture students but also for those studying other fields. Observational drawing survived the widespread use of photography because it was believed to possess qualities that photography did not offer, but even so, it eventually faded away.

Another argument is the fact that freehand drawing has a significant physical component, and this would be a way to connect the body with the mind in higher education, which tends to be almost exclusively intellectual (Block 2019). Freehand drawing is a procedural tool for the work process and for the training of students. This training includes developing hand dexterity and representational skills, as well as the ability to observe one's environment. In neither of these aspects does the drawing play a role or have a value as a finished product, as a demonstration of talent, virtuosity, or even genius, as Ware (1966) stated. Instead, training in drawing is an essential step in the development and liberation of genius.

Figure 62. Drawing classroom, Pierce Building, n.d.

Figure 63. Lawrence B. Anderson and Louis Kahn with students

Freehand drawing was a mandatory course for all MIT students during their first year, and it was taught as an autonomous department, emphasizing memory drawing and speed of execution using various mediums such as pencil, pen and ink, and brush sketching. Biology and geology students were taught specimen drawing, while architecture students were also trained in freehand drawing. However, in 1925, the Division of Drawing was incorporated into the Department of Architecture, and freehand drawing became exclusive to architecture students (in Catalog 1925).

During what we define as the fourth period, which began in the mid-20th century, freehand drawing began to evolve into bold and accelerated perspectives and aerial views. This transformation emphasized the technical and constructive dimension of the representations and marked a departure from the traditional Fine Arts approach, embracing the vision of the modern movement. The overhaul of representation courses, including the Division of Drawing, led to the introduction of Graphics as a course in 1950.

It is worth noting that the relevance of drawing in the curriculum gradually declined, and by 1965, there was no longer a mandatory drawing course. According to Olgyay and Robinson (1985), after the war, Freehand Drawing and Graphics were minimized, and Shades and Shadows and Perspective were eliminated. Instead, the department focused on strengthening studies in urbanism and structures to broaden students' understanding of the engineering and science problems associated with architecture.

These changes reflect two conflicting movements. On the one hand, there was a shift in the character of representations influenced by the modern movement, emphasizing the technical and artistic liberation of architecture, as evident in the students' representations. On the other hand, there was a gradual detachment from the path of science and its methods, which would ultimately shape the identity of the department and the entire school.

The way of science

The evolution of the Architecture Department at MIT from the early 1900s to the late 1960s reflects changes in architectural education throughout the United States. Initially, the department followed the tradition of Fine Arts and placed emphasis on freehand drawing as a crucial component of the curriculum. However, as technology advanced and new materials emerged, the focus shifted to craftsmanship and fabrication.

In the early 1900s, the Architecture Department at MIT faced significant changes in the aftermath of World War I. The enrollment in the program decreased, and many instructors retired or resigned, resulting in an influx of new staff (Kimberly 1996). However, the Fine Arts tradition in the curriculum remained strong, with a focus on the study of past

SECOND TERM.

COURSES I., II., III., VI., VIII. (3), X., XI., XII., XIII.

	Hours of Exercise
Analytic Geometry (28)	60
Inorganic Chemistry (551); Qualitative Analysis; Chemical Laboratory	105
Descriptive Geometry (101)	90
Freehand Drawing (111)	30
French II.[1] (221)	45
English (140)	15
United States History (170)	30
Military Science (990)	45

COURSE IV.

	Hours of Exercise
Shades and Shadows (470)	15
Analytic Geometry (28)	60
Descriptive Geometry (103)	135
Modelling (522)	30
Freehand Drawing (112)	45
French II.[1] (221)	45
English (140)	15
United States History (170)	30
Military Science (990)	45

COURSE V.

	Hours of Exercise
Inorganic Chemistry (551); Qualitative Analysis; Chemical Laboratory	150
Elements of Analytic Geometry (27)	45
Descriptive Geometry (101)	90
Freehand Drawing (111)	30
French II.[1] (221)	45
English (140)	15
United States History (170)	30
Military Science (990)	45

COURSE VII.

	Hours of Exercise
Inorganic Chemistry (551); Qualitative Analysis; Chemical Laboratory	150
Industrial Microscopy (708)	30
Elements of Analytic Geometry (27)	45
Freehand Drawing (111)	30
French II.[1] (221)	45
English (140)	15
United States History (170)	30
Military Science (990)	45

COURSE VIII. (1, 2).

	Hours of Exercise
Analytic Geometry (28)	60
Inorganic Chemistry (551); Qualitative Analysis; Chemical Laboratory	135
Freehand Drawing (111)	30
Wood and Metal Work (137)	60
French II.[1] (221)	45
English (140)	15
United States History (170)	30
Military Science (990)	45

COURSE IX.

See page 61.

[1] Students who have passed French II. before entrance are advised to take German II. For more advanced elective courses in French and German, see Subjects of Instruction, page 141

Figure 64. 1905 course catalog showing the second term of MIT's first academic year. All students were required to take freehand drawing classes, with more hours allocated to the Architecture course. The courses listed are: (i) Civil Engineering, (ii) Mechanical Engineering, (iii) Mining Engineering and Metallurgy, (iv) Architecture, (v) Chemistry, (vi) Electrical Engineering, (vii) Biology, (viii) Physics, and (ix) General Science

achievements and freehand drawing, which was considered an integral part of the program (Ware 1966). Students studied historical drawings and artifacts assembled in the drawing-room and the Museum of Fine Arts. The program included courses in watercolor, pen & pencil, composition & rendering, clay modeling, shades & shadows.

However, the emphasis on drawing lost its relevance, and the act of making became the paramount focus of architectural education. With technological advances, craftsmanship, and fabrication replaced drawing, and the department shifted its focus to these aspects. The motto of MIT *mens et manus*, which emphasizes both knowledge and its application in the real world, became the guiding principle of the department. This shift towards a more practical and technological approach to architecture continued to be a distinctive aspect of the MIT architecture course today (Form 2010).

In the 1920s and 1930s, new architectural styles, materials, and technologies influenced the courses offered in schools of architecture. However, William Emerson, who led the Architecture Department at MIT between 1919-1939, was a former student of Ware and studied at the Ecole des Fine Arts itself. Although he supervised the adaptation of the architecture curriculum to new trends, he sought opportunities for students to travel and study historical European architecture and conduct archaeological research (Sharon 2016).

During World War II, the department faced significant challenges due to the mobilization of architecture students for the war effort (Olgyay and Robinson 1985). The focus of the war was on electronics, and architecture was not seen as a necessary discipline. The years following the war were marked by a return to full operation, with many students returning from military service, and the instructors had a clear perception that the students who had returned to school after the war were operating at a much higher level (Olgyay and Robinson 1985).

The integration of the Architecture Department at MIT into a more scientific and technological position occurred with the transfer of the deanship from William Wurster to Pietro Belluschi in 1950 (Olgyay and Robinson 1985). Belluschi emphasized the importance of a technical approach that made use of MIT's laboratories, courses in materials, and subjects such as sanitation, acoustics, illumination, and heating and ventilation. He believed that architecture was an art, but technology was the means of architecture. American architecture schools preferred the art of design to be reinforced by research in humanities, science, and engineering.

Belluschi also sought a physical environment that expressed American culture, which encompassed the scientific outlook and used modern industrial methods and materials while providing aesthetic fulfillment. Lawrence B. Anderson, the dean of the department in 1970, wrote in the course catalog that architecture and planning were deeply influenced by

social, economic, and technical factors, and the department emphasized research in these areas.

Visual narratives of change

As outlined in this section, our aim was not only to analyze thesis drawings but also to connect them with the curricula of the corresponding years, thereby intersecting two perspectives: the alignment of architectural education principles and their manifestation in students' work.

So, what do these drawings reveal? Firstly, they depict the evolution of pedagogy, illustrating shifts in program offerings and changes in courses related to drawing and representation. Drawing goes from being a mandatory discipline for all courses at the institution, with its own department, to being incorporated into the architecture department and practically disappearing. From this, we also understand how the pedagogical role of drawing has changed, starting as a characteristic factor of the entire school, central to the pedagogical strategy and something everyone should master, to becoming associated with students' personal choices.

These drawings also serve as indicators of design trends and shifts in representation. They highlight the direct relationship between architectural language and its visual portrayal, demonstrating how changes in architectural forms influence forms of representation. Furthermore, they reflect broader cultural and social contexts, including the emergence of modernism and the transformative impact of events like World War II on the institution's trajectory.

While our study refrains from making explicit correlations, it underscores the significant influence of both internal and external factors on the institution and our research focus. Conducting such studies relies heavily on available historical evidence, often fragmented and requiring meticulous interpretation. In this instance, our study benefited from the institution's systematic collection, digitization, and organization of visual materials, a critical step enabling comprehensive analysis within this field.

Chapter 6 Discussion and perspectives

6.1 Presentation

6.1.1 Problem

In this research we consider the intersection between two divergent perspectives. On one hand, we concern ourselves with understanding the widespread digitization of design processes in recent decades, prompting questions about the relevance of traditional modes of representation and their role within architectural education (Yossef and Salama 2013). As our bibliometric analysis (see 1.1.2 Relevance) indicates, research on freehand drawing has held a less prominent position among topics related to design education and representation since the 2000s, often ranking behind subjects such as digital modeling, manufacturing, or BIM.

On the other hand, as previously mentioned, freehand drawing continues to be acknowledged as an essential element of architectural education by various authors, including Goldschmidt (1989; 1991; 1992; 2004; 2014; 2017), Gero (1988; 1998; 2006; 2020), and Tversky (1996; 2003; 2009; 2015). Additionally, the latest UNESCO-UIA charter (2023) underscores the importance of students acquiring proficiency not only in digital tools but also in drawing skills, which reflects an ongoing shift in the field.

Hence, the primary aim of this research is to gain a comprehensive understanding of the role and significance of freehand drawing in design education today. Through this study, we seek to elucidate how freehand drawing is integrated within design studios and explore the reasons behind its use. Ultimately, this analysis will help us explore potential directions for both educational practices and research in this field.

6.1.2 Approach

One of the aspects highlighted in our literature review (see 1.4 Review) is not related to the topic itself but rather to the way the topic is examined. This concerns the methodology applied in the various studies considered. As we have seen and emphasized, a significant portion of studies focusing on architecture and design education is not grounded in evidence-based observations. In many cases, anecdotal data or mere speculations based on teaching experiences are used. Methodological procedures are either unclearly stated or unsupported, suggesting that they may not have been followed rigorously, and the research

was conducted somewhat intuitively and unsystematically. This methodological gap, identified during the literature review, is a key issue we aim to address in this research.

Thus, in Chapter 3 of this thesis, we provide both a narrative literature review on the methodological definition of educational settings research based on fieldwork and the actual process of defining this research, serving as a practical example.

In the study presented in Chapter 4, which constitutes the core of the findings in this research, we addressed the problem through a multi-case study design. By conducting fieldwork three distinct case studies, which correspond to three schools of architecture (POLIMI, FAUP and MIT), we intended to gather evidence that would allow us to answer the research questions. For this, a wide range of design studios were observed, going through the different years of the course, but also diversified, considering different types of classes.

In Chapter 5, we present four complementary studies that, by their nature, delve into various aspects that have not been addressed in Chapter 4. The methodology in the first three studies follows the general procedures of the research, primarily relying on direct observation. These studies focus on the drawing courses at FAUP, their relationship with design studios in the same year, and design teaching at FAUP and POLIMI during the pandemic with remote teaching. The fourth and final study is based on archival research, combining students' drawings archived at MIT from 1870 to 1960 with corresponding curriculum programs, allowing us to trace the transformations in the school's approach to representation and drawing in design studios.

6.1.3 Organization

In this chapter, we will begin by examining the significance of freehand drawing in design education. We will summarize the key findings presented in Chapter 4 and Chapter 5, providing an overarching perspective on the main results and their interconnections. This will contribute to a comprehensive understanding of their implications within the broader research context.

Moving forward, we will delve into the three research questions, drawing upon relevant literature, as previously emphasized in the literature review. It is worth noting that most of the literature does not directly address our research questions, requiring the collection of pertinent information indirectly. We will then establish connections between this gathered information and our empirical data, highlighting areas of alignment, divergence, and novel insights that have arisen from our research.

We will then correlate our evidence-based observations with the existing theories examined in the theoretical framework. This comparison will enable a discussion of the practical implications of these findings in both educational and research contexts. Finally, given the

exploratory nature of the third research question, we will outline a series of future perspectives regarding the use of freehand drawing in design education.

6.2 The relevance of freehand drawing

Here, we intend to highlight some key findings from this research and interpret them in the context of the relevance of freehand drawing in design teaching. To do so, we will draw upon the main results from Chapter 4, which includes the three case studies, and Chapter 5, featuring complementary readings. It is important to note that these data are contextually situated, meaning they were gathered from specific institutions without manipulation of observed behaviors or situations within a defined time frame.

Starting with the design process, it is noteworthy that there is a substantial presence of freehand drawing in the design studios observed across all three schools (see 4.2.2 Design process: Freehand drawing), regardless of whether it is formally taught. When examining its frequency, we can begin to discern their significance in these institutions. We find that at FAUP, freehand drawing is most prevalent in the design process, followed by MIT and then POLIMI.

Analyzing the functions of these drawings, we observe variations among the schools. In FAUP and MIT, freehand drawing is mostly used as a design tool, while at POLIMI, it primarily serves as a presentation tool. Another noteworthy aspect of the drawing functions is the practice of observational drawing, which is somewhat relevant at FAUP but practically non-existent at the other schools (figure 60).

Considering the types of drawings made by students, we note a substantial difference among the three schools. While at POLIMI and MIT, the majority of drawings consist of technical representations such as plans, sections, elevations, and diagrams (figure 61), at FAUP, there is a significant prevalence of perspective drawings. The use of freehand drawing to depict perspectives holds less relevance in the other two schools, possibly stemming from formal drawing training that places substantial emphasis on observational drawing. Consequently, we observe that students at POLIMI and MIT face some difficulties with perspective (see 4.2.2 Design process: Students' difficulties).

Regarding the support used, it is important to highlight the extensive use of tracing paper by FAUP students, which is less common in the other two schools. This may influence the subsequent point concerning the balance between static and dynamic representations.

When associating this data with the balance between static and dynamic productions by students in the three schools, we find that FAUP reveals a considerable prevalence of dynamic representations, followed by MIT and then POLIMI (see 4.2.2 Design process: External representations). Interestingly, we observe an equal propensity among FAUP

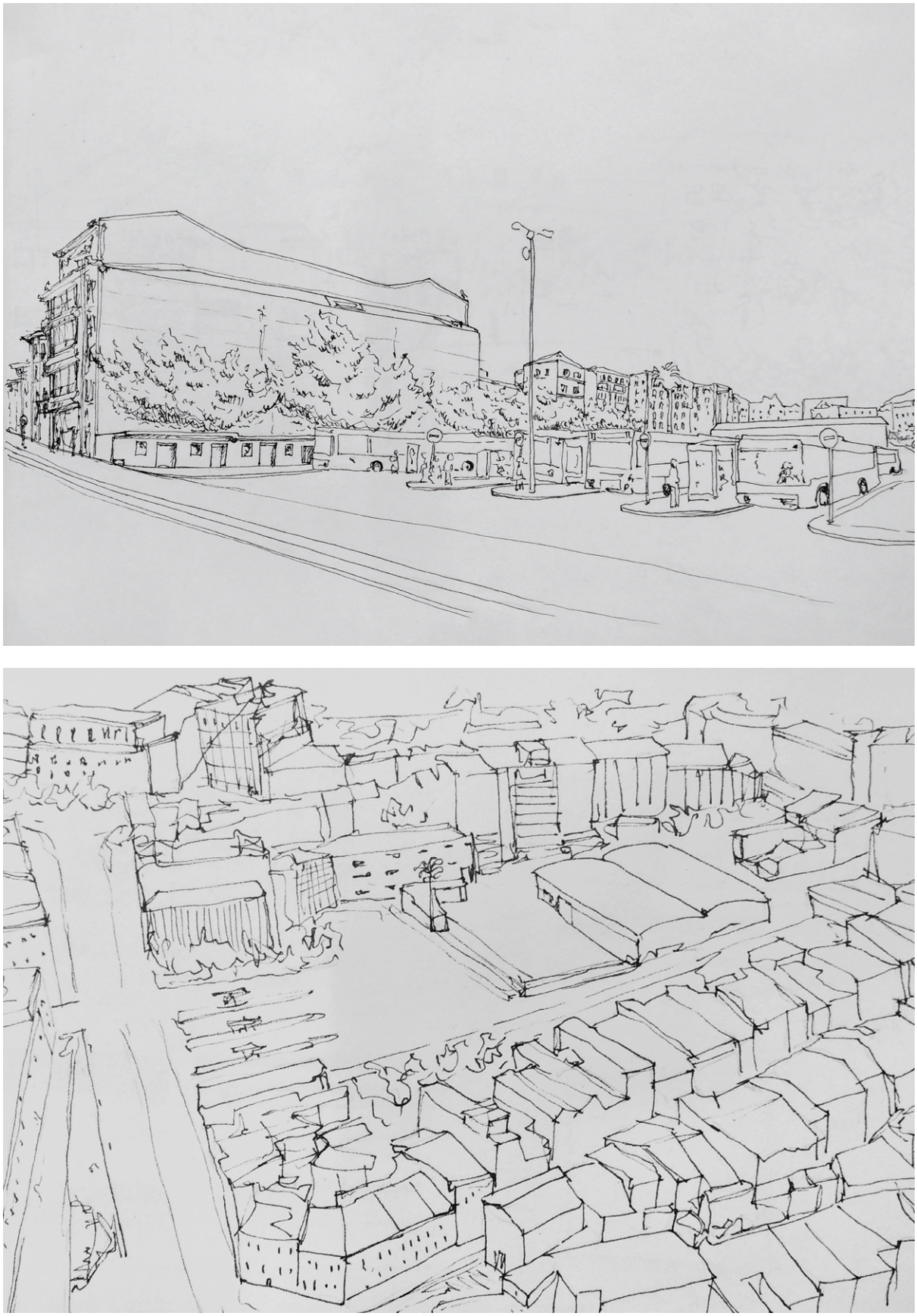


Figure 65. Student's drawings of the intervention site, FAUP, 2021

Figure 66. Student's technical representations using freehand drawing, MIT, 2022

students for dynamic representation with physical models, which is not followed at MIT (see 4.2.2 Design process: Physical models).

These results allow us to interpret that, irrespective of students having formal drawing training within their curriculum, they can use it in both individual design processes and design critiques as a means of interaction with instructors. The data also indicates that the capacity to employ drawing dynamically in design development is directly linked not only to the instruction in drawing but also to the way in which it is utilized.

What sets them apart primarily is the frequency with which they use freehand drawing—in the case of design critiques, this seems to be related to students' lack of confidence—and the types of drawings produced, with observational drawing and perspective being practically exclusive to FAUP.

However, what we also observe at FAUP is that both the frequency of drawing and the use of perspective significantly decrease after the first two years, where drawing is mandatory, transitioning into scattered activity performed by a few students, thereby approaching the numbers seen in the other two schools.

Another aspect that distinguishes students in the three schools is a propensity among FAUP students for dynamic representations that favor design moves. MIT students also exhibit a propensity, albeit to a lesser degree, especially with drawn representations and less so with physical models. Conversely, we note that POLIMI students frequently report issues related to design fixation—we see in the functions attributed to drawing that it is not widely used as a design tool.

However, this aspect does not appear to be solely explained by the drawing courses that FAUP students take, as this dimension is not explicitly explored. Furthermore, at MIT, where there are no drawing courses, students also exhibit this capability.

Instead, concerning FAUP, it seems essential to consider the approach of instructors in the design studios during the first two years, where significant emphasis is placed on the work process and where drawing is actively integrated (see 5.3 Drawing and design). It appears that these design studios play a crucial role in the development of the dynamic aspect of drawing. This dynamism extends beyond drawing to include greater ease in the dynamic use of representation, even in physical models, among these students.

Considering the significance of drawing in design critiques, we observe a notable aspect. Despite drawing being taught only at FAUP, we find that in all three schools, drawing is extensively used in design critiques, both by instructors and students, emerging as the primary mode of interaction following speech and gestures (see 4.2.3 Design critiques: Modes of interaction).

While the values are more pronounced among instructors in all three schools, we also see a high level of use among students, with FAUP displaying the highest use, followed by POLIMI and then MIT—maintaining a similar ratio between instructors and students.

Instructors predominantly use freehand drawing for design composition in all three schools, with POLIMI also employing it extensively for discussing presentation aspects of the work, FAUP for constructive aspects (figure 62), and MIT for prototype production (see 4.2.3 Design critiques: Freehand drawing by instructors). Likewise, among students, drawing is primarily used for design composition, with POLIMI also utilizing it for analysis (of the site or precedents), and MIT for prototype production (see 4.2.3 Design critiques: Freehand drawing by students).

The most produced types of freehand drawings by instructors in all three schools are rigorous representations, graphical notes, and schemes (figure 63), with FAUP also exhibiting a high production of perspectives, mirroring what we observed with students from the same school in the design process. Among students, the types are similar, with technical representations and graphical notes being the most frequent. Notably, during design critiques, FAUP students do not use perspective often.

Regarding the supports for freehand drawing used by instructors, plain paper is the most common in POLIMI and MIT, whereas at FAUP, students' own representations are employed. This seems to be related to the manipulative nature of drawing, with POLIMI and MIT predominantly using non-manipulative drawing, while manipulative drawing prevails at FAUP.

The data among students is similar, with plain paper being the most commonly used support at POLIMI and students' own productions at FAUP, while digital support (tablet and e-reader) is most frequent at MIT.

Considering the suggestions and requests from the three schools, we note that the most common is for students to produce a new representation (see 4.2.3 Design critiques: Critiques contents and actions), with freehand drawing being the most frequently requested form of representation, followed by technical representations.

What the data allows us to interpret is that freehand drawing holds significant importance in design critiques across all three schools. Furthermore, freehand drawing in these schools, despite being formally taught only at FAUP, stands out as the most crucial form of representation, widely used by both instructors and students.

Differing from the design process, where students employ freehand drawing as one of many representation tools as part of their individual work development, in design critiques, freehand drawing is the most commonly used form of representation by all, leading us to consider its significance primarily as a didactic tool (see 5.3 Drawing and design).

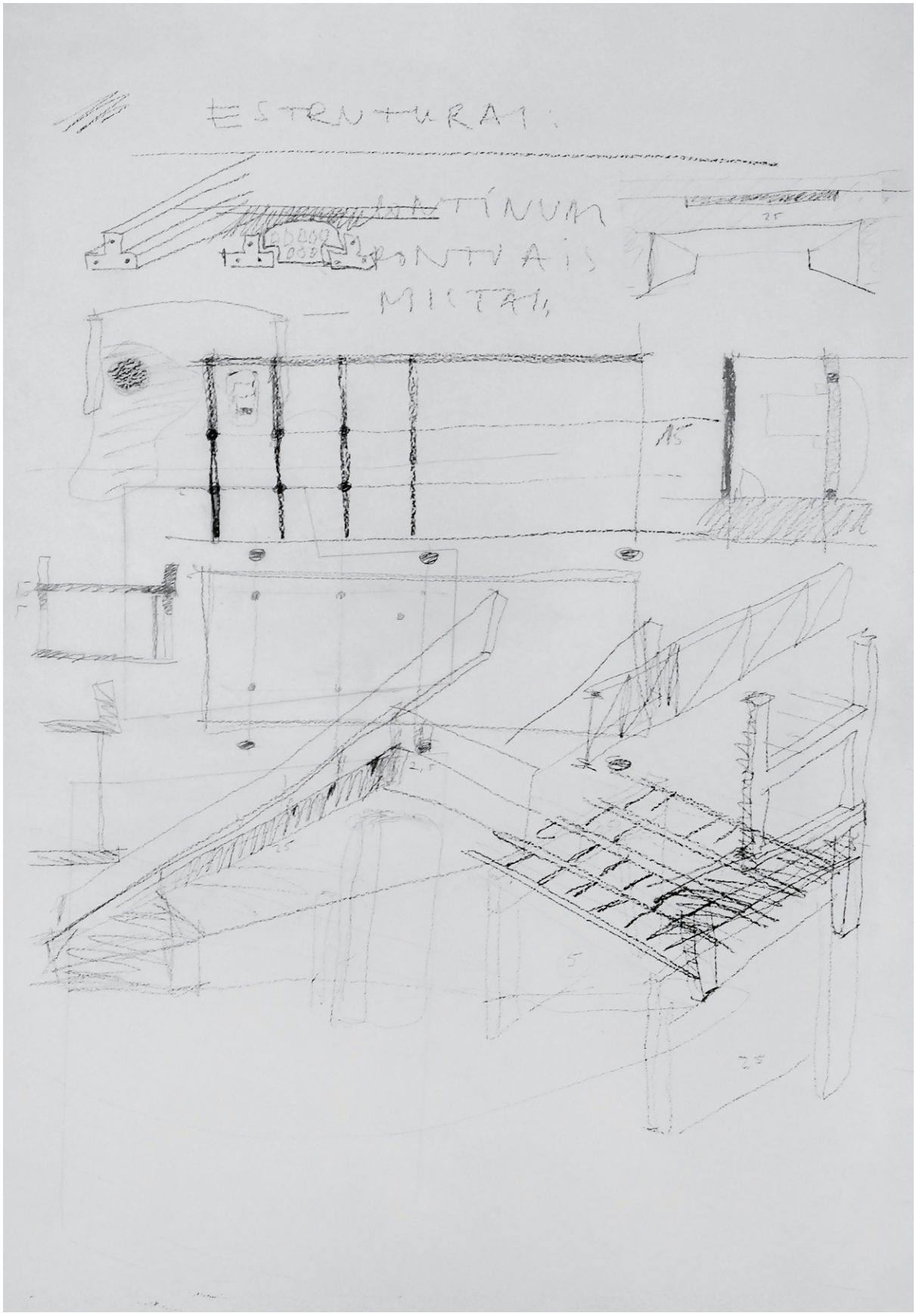


Figure 67. Instructor's drawing explaining a constructive issue, FAUP, 2021

Figure 68. Instructor using freehand drawing for annotation on student's work, FAUP, 2022

Once again, we observe that even students without formal drawing training are capable of using it as a mode of interaction during design critiques, as well as employing it manipulatively. What we see is that the lack of training in some cases seems to demotivate them from doing so due to a lack of confidence and nervousness in the presence of the instructor.

The majority of instructors in all three schools recognize the importance of freehand drawing in the work process, particularly to counter design fixation, as most requested new representations are freehand drawings, followed by technical representations.

It is also worth noting that even when a student does not use drawing, the fact that the instructor does is beneficial for the student. Instructors drawing on students' work can lead to design moves, overcoming the student's design fixation challenges. Additionally, instructors can teach aspects of composition, construction, or indicate precedents through quick sketches.

6.3 How is freehand drawing used?

6.3.1 Existing literature

Regarding the first research question—how is freehand drawing used in architectural design teaching?—we see that existing literature divides it into: (i) the part or component of the design studio where freehand drawing is present; (ii) the stage of the teaching process; (iii) its associated functions. The values indicated below follow the results of the literature review (see 1.4 Review).

Regarding the first aspect, the part of the design studio where freehand drawing is present, almost all literature agrees that it is part of the design process (n=18). In this regard, Putra et al (2022) state that manual drawing practice is an important stage of the design process, even though students nowadays are becoming less familiar with its use. More emphatically, Soygenis, Soygenis, and Erktin (2010) describe freehand drawing as a rough, quickly made drawing that plays a vital role in the design process.

Although to a lesser extent, a significant part of the literature associates freehand drawing with the teaching process (n=11). Olmos (2006) describes design training as a reflective practice involving knowledge based on the production and manipulation of representational media, such as sketches, drawings, and models. On the other hand, a small part of the literature also highlights the importance of freehand drawing in design critiques. As noted by Eren and Yılmaz (2022) and Hsu et al (2020), during design critiques, instructors and students discuss the design solution supported by 2D design drawings and physical models and communicate using speech and sketching on paper or whiteboards.

Moving to the second aspect, concerning when freehand drawing is used within the design studio, the most common position in the literature is that drawing is primarily present in the early stages of the design process (n=8). As Hsu et al (2020) suggest, more abstract representations such as diagrams or sketches are used in the conceptual stage of design, and as the design develops, representations of the design solution become more rigorous and detailed. Only one author in the consulted literature mentions that freehand drawing is also used in later stages, although it is rarely part of the final study (Taraszkiewicz 2021). Interestingly, the same author points out that students continue to use drawing throughout the process when discussing ideas with the instructor.

Finally, concerning the third aspect about the functions or types of use associated with freehand drawing in the design studio, the most cited use in the literature is that of drawing as a form of visual thinking (n=16). As Akalin and Sezal (2009) state, drawing is closely linked to thinking. Putra et al (2022) also note that freehand drawing is an efficient way of thinking, mentally stimulating, producing mental impressions, and critically supporting the development and correspondence of complex spatial ideas.

Furthermore, a significant number of references in literature consider freehand drawing as a visualization tool (n=13). Yossef and Salama (2013) point out that drawing is a rapid way to graphically demonstrate an image, idea, or principle. This is because, as mentioned by Eren and Yılmaz (2022), designers are among professionals who require mental visualization of objects and phenomena and the ability to interpret and work with these images. Therefore, their training places a strong emphasis on learning visualization techniques.

Although mentioned less frequently in the literature, communication (n=9) also emerges as one of the functions of drawing. Taraszkiewicz (2021) refers that since design is rarely an entirely individual activity, especially in an educational context, freehand drawing allows for the rapid sharing of thoughts and visions as a complement to verbal communication. Soygenis, Soygenis, and Erktin (2010) refer to these drawings that serve communication in the studio environment as “talking sketches,” of which drawings produced in the interaction between instructors and students are a paradigmatic example.

There is also a reference in the literature to drawing as an observation tool (n=8). Putra et al (2022) characterize the act of drawing as a practice of “seeing,” connecting the act of drawing to one’s surroundings and facilitating a more comprehensive spatial understanding. This is one of the aspects that Akdag (2018) points out as one of the advantages of drawing over digital media for supporting the perception of visual-spatial features.

Additionally, drawing is mentioned as a problem-solving tool (n=5). According to Akalin and Sezal (2009), sketches store design solutions seem to be essential for recognizing conflicts and possibilities. Akdag (2018) also states that many designers continue to resort to pen and

paper during problem-solving moments, recognizing the advantages of traditional media in this regard.

Another function associated with drawing is that it serves as an annotation tool (n=4). Nováková, Achten, and Matějovská (2011) note that just as everyone needs to take notes when solving a complex problem, designers take visual notes in the form of sketches, drafts, and texts, ultimately defining a personal visual language.

6.3.2 Evidence-based observations

Design and teaching process

It seems essential to distinguish between design and design instruction, as previously mentioned. According to Milovanovic (2019), this differentiation can be settled as learning objective (design) and the educational approach (design teaching). These are integral aspects of design education, but due to their distinct characteristics, they should be considered independently. This division is evident in how we present the results of this research, clearly dividing the analysis into design process and teaching process.

While there is a majority in the literature emphasizing the role of drawing in the design process compared to design teaching, our data highlights the relevance of drawing in education. Despite a considerable number of students who engage in freehand drawing as part of their design process in all three schools, we observe that in design critiques, whether by students or instructors, drawing has a more notable frequency and relevance, as previously mentioned. In all cases, it is the most commonly used form of representation by both parties.

Design stages and design critiques

A position often advocated in the literature, which suggests that freehand drawing is primarily used in the early stages, is not reflected in our data, whether in the early stages related to the design process or in the guidance provided by instructors. Few authors mention that drawing is also followed in the advanced stages.

In all three schools, drawing is consistently present throughout the various phases of the design process, from the initial conceptual stages to the final project details (figure 69-70). What occurs is that in the early stages, tools that allow more ambiguity, freedom, and flexibility are predominantly used, of which drawing is not the sole option. Subsequently, the transition is made to more precise representations. However, even in the advanced stages, we see drawing complementing the more rigorous forms of representation, serving

various purposes as we have already discussed—annotation, visualization, visual thinking, or communication.

In the case of design critiques, this aspect is particularly evident. Throughout the design process, freehand drawing is the most frequently used form of representation by both students and instructors. In many cases, it is the only form of representation used in design critiques, although its uses vary widely among schools and instructors.

Digital freehand drawing

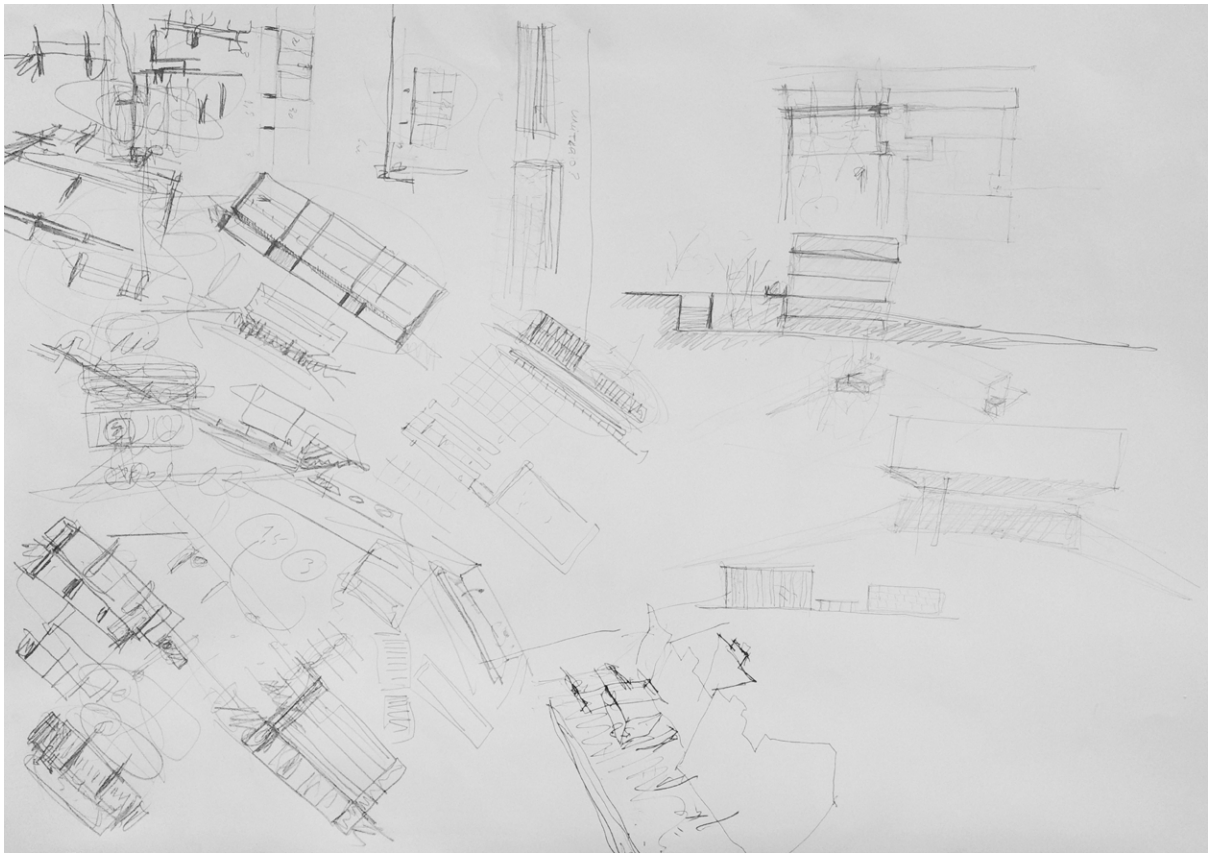
While the literature does not specifically address this aspect in relation to the first research question, it is important to note the relationship between conventional and digital freehand drawing. Eren and Yılmaz (2022, 2) make this distinction, stating that "conventional drawing technique includes hand drawings, and digital drawing technique includes drawings made with drawing software."

What our data indicate is that there is not a significant difference between using one or the other in the context of design education. On the one hand, we have the case of MIT, where students actively use tablets, e-readers, and laptops for digital drawing without any discernible impact on the functions of drawing. Quite the contrary, it appears that MIT students are capable of using drawing dynamically, whether digital or conventional. On the other hand, during the pandemic period, we observed occasions at FAUP and POLIMI where instructors used digital pens or just a mouse to interact with student productions, yielding impressive results (figure 71).

What we have seen is that digital drawing has opened new possibilities, enhancing the inherent capabilities of freehand drawing. For example, it allows direct interaction with software—students can share their desktops with CAD or BIM software running (figure 72)—or with analog productions such as digitized freehand drawings (figure 73) or photographs of physical models (figure 74).

The roles of freehand drawing

One issue with the term "visual thinking" is its broadness, making it less practical when collecting and analyzing data, despite being widely referenced in the literature. In the attendance of design studios, the use of the term "visual thinking" can encompass nearly all activities related to representation, including analysis, and designing, whether through freehand drawing or any other form of representation.



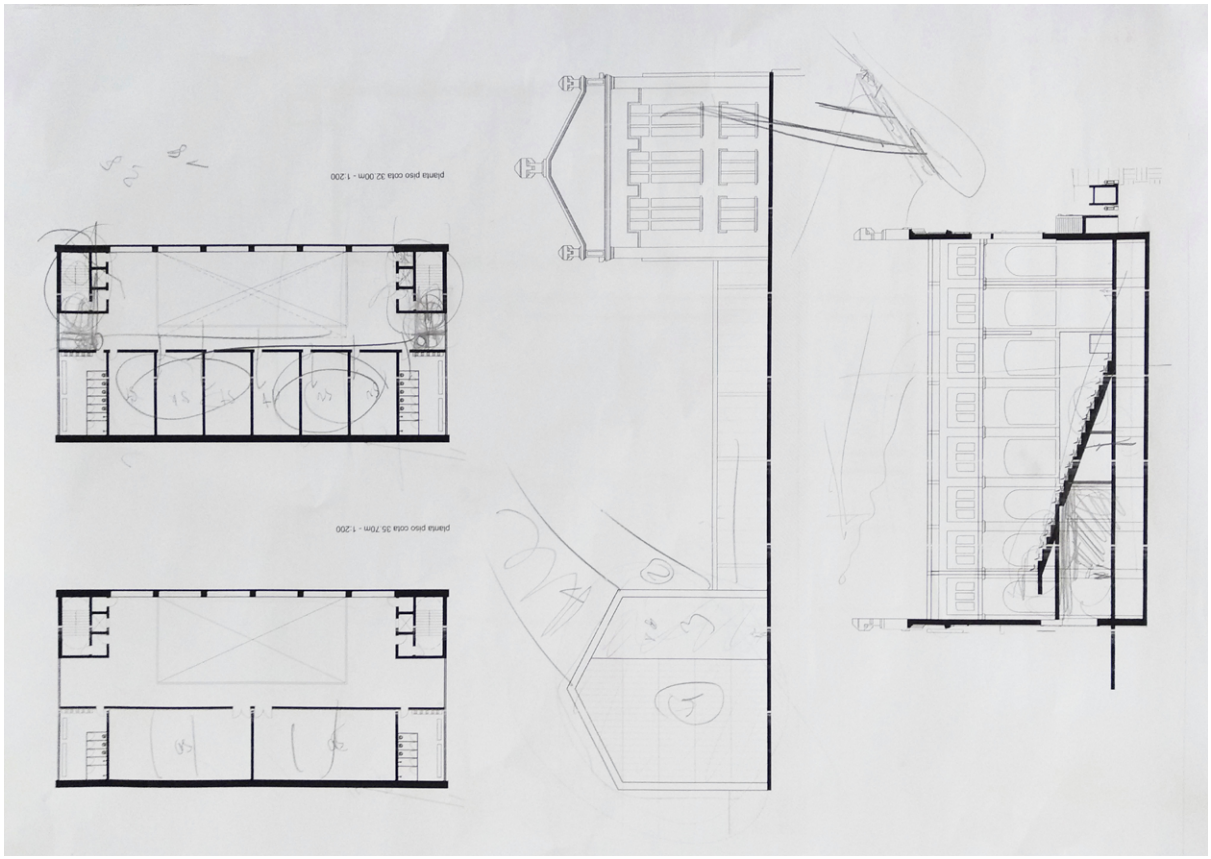


Figure 69. Freehand drawing used by a student in an initial design phase, FAUP, 2021

Figure 70. Freehand drawing used by a student in a final design phase, FAUP, 2021

As we discussed in the theoretical framework, visual thinking, along with visual communication, constitutes two major categories under which all other functions can be organized.

In our collected data, both in the context of the design process and design critiques, we see that the most frequent use of drawing is as a design tool in all three schools, except for the design process at POLIMI, where drawing used for presentation also has a higher frequency.

Regarding design critiques, the focus on design remains the most relevant, whether among instructors and students. Within this context, we can distinguish between composition, construction, and production, as it becomes clear that in some critiques, these dimensions of design are discussed independently—for example, solely addressing the constructive aspects. However, as we will specify later on, annotations themselves play a significant role in visual thinking and contribute to design moves.

Visualization

Regarding freehand drawing as a form of visualization, if we are discussing spatial visualization, our data indicate that the most commonly used form by students is technical representations—plans, elevations, sections, axonometries—with the exception of FAUP, where free perspectives hold greater significance. In this regard, we observe that in the other two schools, the use of perspective drawing is less prominent.

In this aspect, the data concerning design critiques are similar, with technical representations being the most frequent among students and instructors, except at FAUP, where perspective drawing plays a more significant role.

Communication

Regarding drawing used for communication, we need to make a conceptual clarification. In the context of students' design process, we can primarily see this communicative dimension of drawing through presentation drawings, which are highly relevant at POLIMI and MIT, while being almost negligible at FAUP. We are referring to drawings primarily used to present the design project. However, as Herbert (1988) points out, all these drawings—including those made to facilitate design moves—despite being created with a private nature, can take on a public nature. Therefore, all drawings produced can serve also for communication.

On the other hand, we observed that during design critiques, freehand drawing plays a significant role in all three schools, both for students and instructors, emerging as the

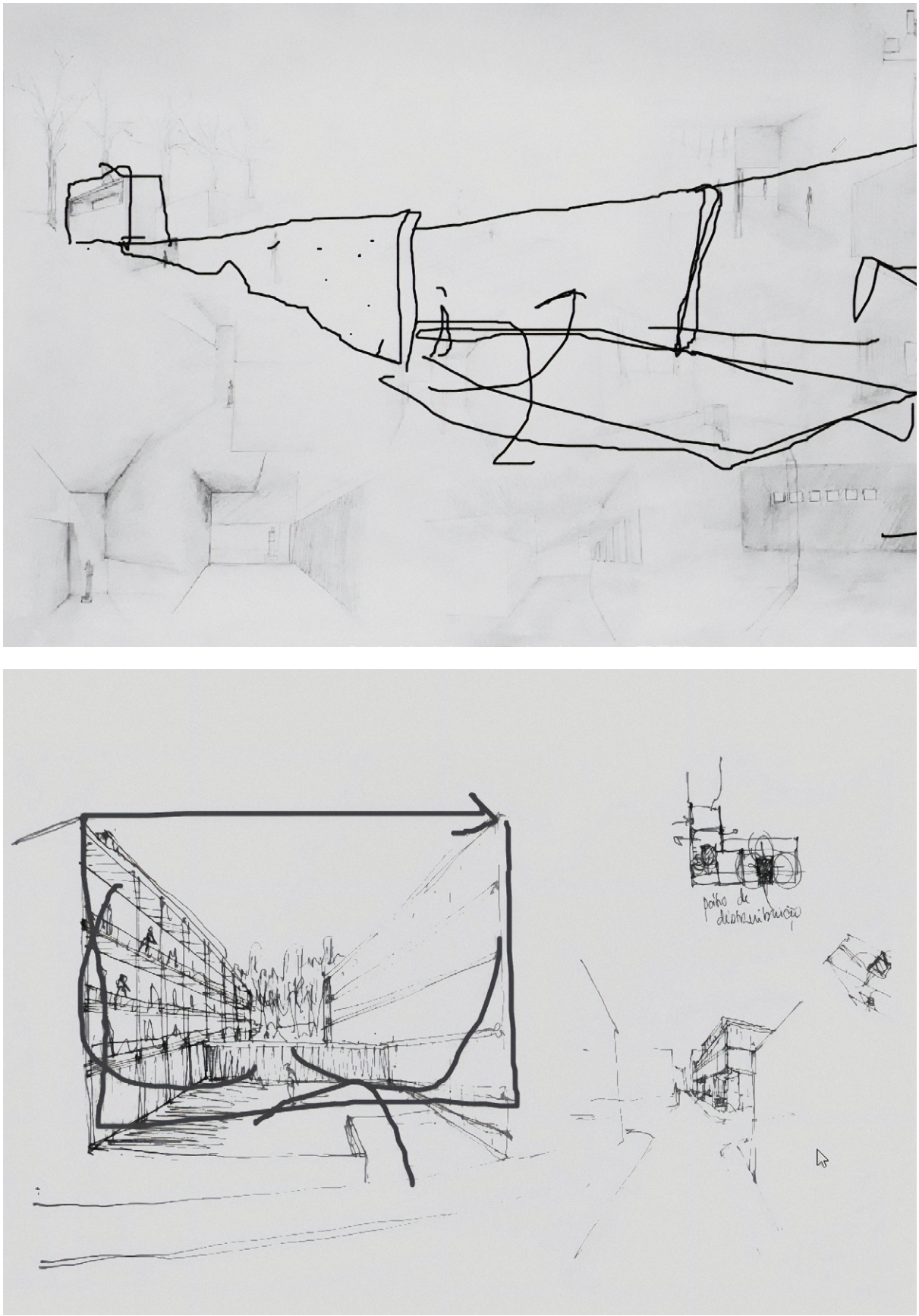


Figure 71. Shared screen: Instructor's drawing on student's work, FAUP, 2021

Figure 72. Shared screen: Student's drawing on his own work, FAUP, 2021

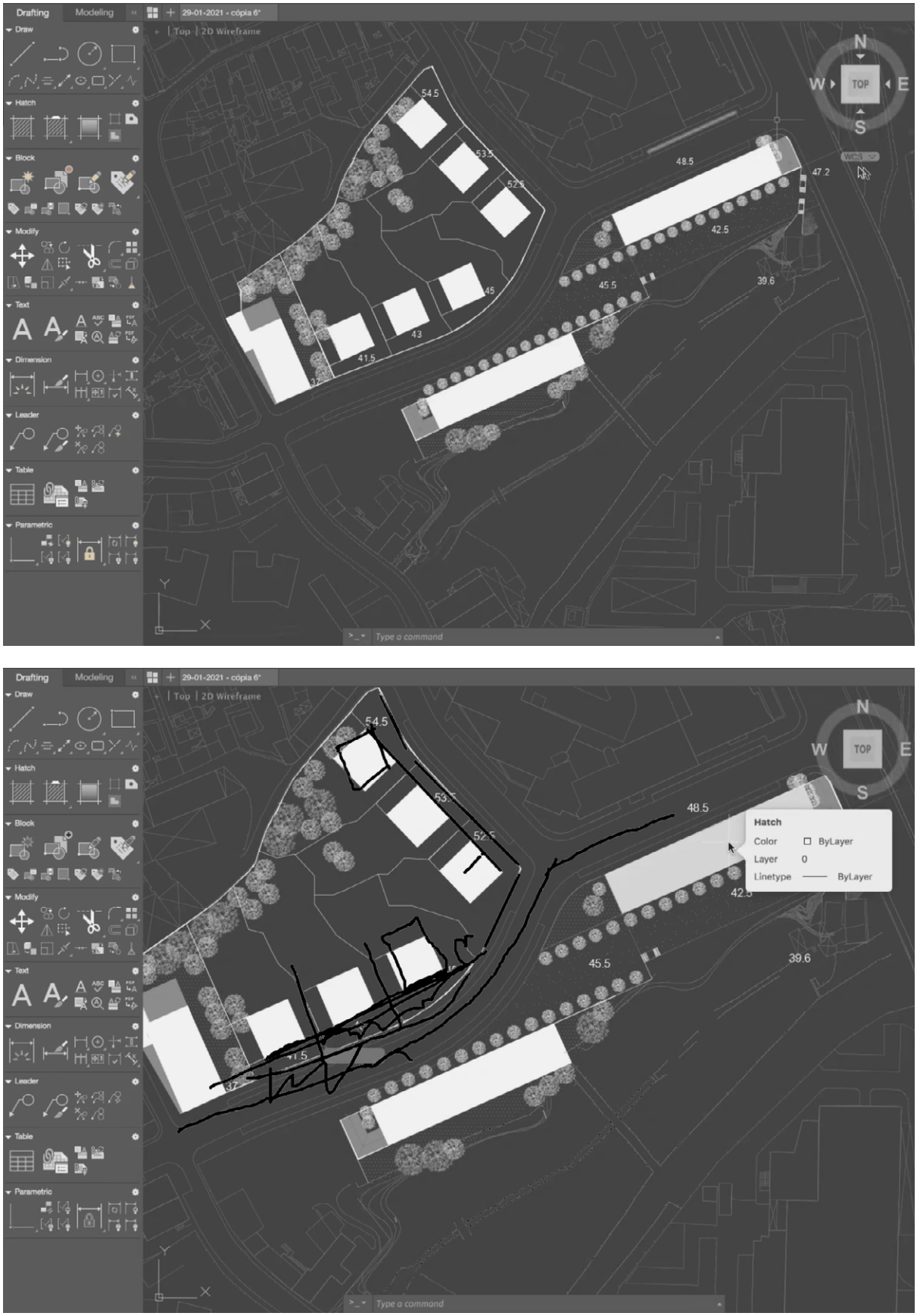


Figure 73. Shared screen: Instructor using digital drawing on a Autocad file, FAUP, 2021

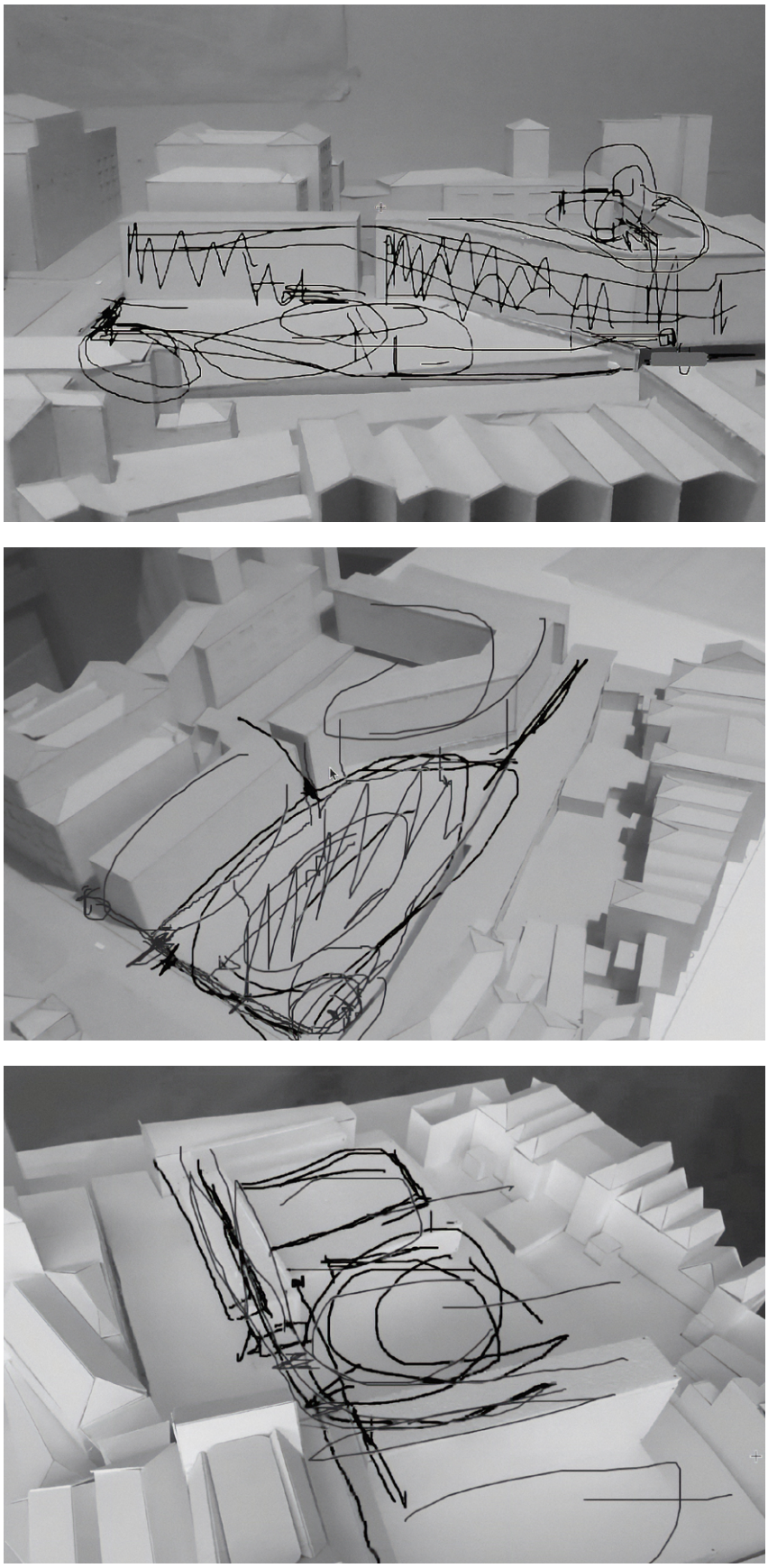


Figure 74. Shared screen: Instructor using digital drawing on physical model, FAUP, 2021

primary form of representation used for interaction—what we refer to as "modes of interaction"—that is, supporting communication between students and instructors. This aspect is so crucial that in certain cases, there is no alternative to freehand drawing to fulfill this function.

Observation

As for the function of drawing used as an observation tool, we see that in all three schools, it is only relevant at FAUP, with a minimal percentage at MIT, and no recorded occurrences in POLIMI. Here, we are talking about a function primarily carried out by students.

Therefore, it is evident that this type of drawing is directly associated with the teaching of drawing in the architecture course, and its presence is primarily due to the intersections between these courses (see 5.3 Drawing and design). In FAUP, in addition to students learning to draw through observation and this type of drawing being widely used by students in the drawing course, we also see in design studios, especially in the first-year design studio, instructors requiring students to follow the same approach as in drawing courses (figure 75).

Instructors ask students to go on-site, and in addition to traditional precise surveys, instructors also request observational drawings, which serve as a form of impressive surveys. In the other two schools, this type of drawing has minimal expression, limited to occasional instances.

This is also evident due to the fact that in the first two years of the curricular plan, students are asked to create several observational drawings in the design studio. In other words, they do not do this spontaneously but rather because instructors request these materials. Once instructors stop requesting this type of drawing, a significant portion of students cease to make them.

Annotation

Based on our observations, we consider annotations or notes as a type of interactive freehand drawing used with another representation to add information, correct, or transform, or simply highlight an aspect—for example, hand-drawn notes made on a CAD section (figure 76). It is a rather elementary form of freehand drawing that does not require advanced skills, yet it appears to be one of the most relevant uses of drawing in the design studio.

Although these annotations are also used in the design process, they do not hold particular significance in all three schools. However, we have observed that this type of drawing is

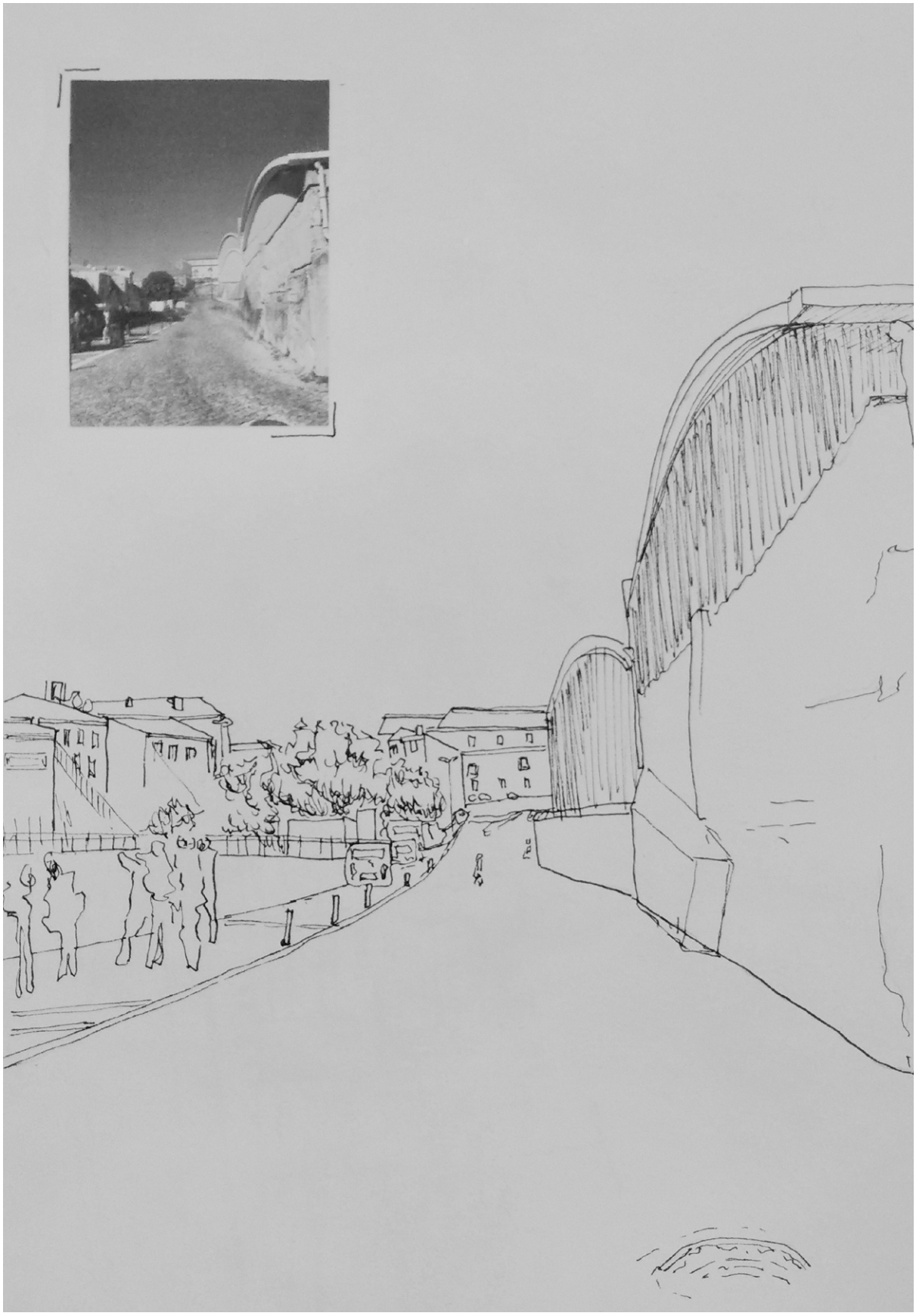


Figure 75. Student's drawing of the intervention site, FAUP, 2021

especially relevant in the context of design critiques, with extensive use among students and instructors. A situation where these annotations became particularly evident, highlighting their importance in design critiques, was during the pandemic when students and instructors created them in a digital environment. At that moment, the interactive aspect of annotations became apparent—and in their simplicity, they facilitated design moves.

6.3.3 Implications for research

One of the implications of our study, consistent with some existing literature, is that freehand drawing is not merely seen as a form of representation or just a design tool but rather as a central — and, as we have seen, a vital — component of design education (Purcell and Gero 1998). While drawing offers several advantages when used to support the design process, we observed that in the context of design critiques, where graphic or visual interaction between instructor and student is a key component, freehand drawing is the most commonly used mode of interaction in all three schools, regardless of students' training in drawing.

Hence, regardless of what happens in professional practice, which, as we have seen, has obviously influenced what occurs in an educational context, drawing continues to hold great significance in design teaching. In this regard, recognizing its decisive importance in teaching processes seems to justify its relevance, regardless of whether it is subsequently used in practice or not.

In this context, we align with the literature that suggests that, to date, in an educational setting, drawing is irreplaceable (Špaček et al 2016; Akalin and Sezal 2009). It is irreplaceable not because there is a persistent insistence on retaining it in design education for traditional reasons, for example, but because there is no alternative that can offer the same possibilities as freehand drawing does, without some form of loss if it were to be replaced.

Milovanovic (2019) and Goldschmidt (1991) also concur on the importance of freehand drawing, especially in design critiques. Likewise, Purcell and Gero (1998) suggest that drawing has been viewed primarily as a skill rather than an integral part of the design process, where its significance is even greater in an educational context.

One implication of our study, which is not explicitly addressed in the literature, is that in a design studio, students do not require formal drawing training to be able to use it. We are referring here to a basic use of drawing, from which any student can benefit. Furthermore, and perhaps more importantly, even without formal training, students can use freehand drawing dynamically, thereby overcoming issues related to design fixation. Our data point to this, is particularly with MIT students, who use drawing in a somewhat intuitive manner without prior training yet are capable of using it dynamically.

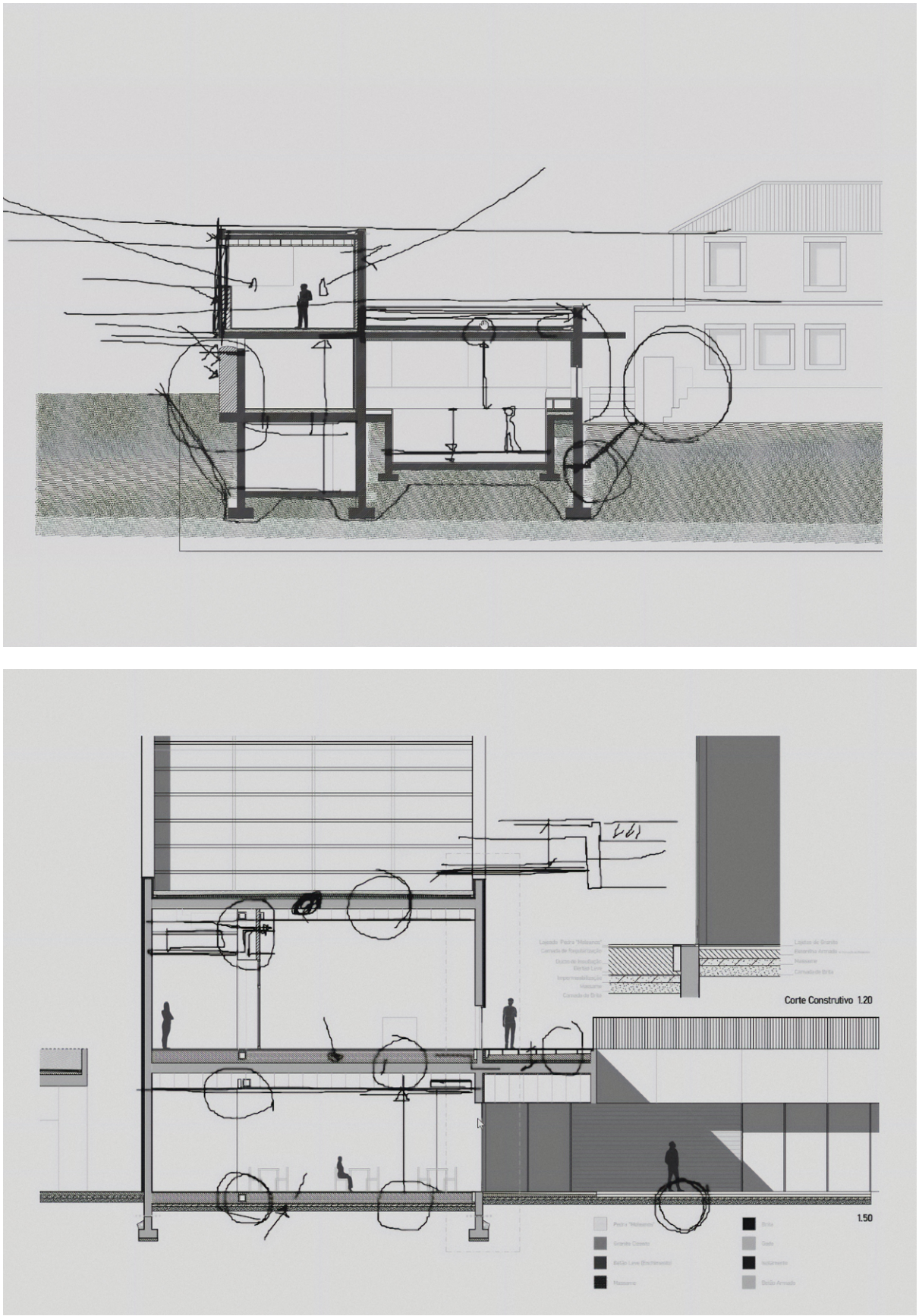


Figure 76. Instructor's annotations on student's work, FAUP, 2021

It is, however, necessary to consider that while some students within MIT use freehand drawing, and among them, some use it dynamically, many students remain outside this group. This is an argument presented at FAUP for the continued training in freehand drawing. The expectation is that all students come into contact with freehand drawing techniques, learn to use them, and have the choice to use them in the future. In practice, however, we observe that many students stop using drawing as soon as they are no longer required to do so and gradually use it less and less.

One point our data support, which is rarely addressed in the literature—as we have seen, only one study out of the twenty considered in the literature review—is that freehand drawing spans the entire design process, from the early conceptual phases to the final detailing moments.

In literature, freehand drawing is often associated primarily with the early stages of design, with more rigorous representation tools such as CAD being used later. However, we observe that drawing continues to be present, often together with digital tools. Even if it does not appear in students' individual design processes, we consistently find it in design critiques. Only two authors in the literature we reviewed mention the presence of drawing in design critiques (Taraszkiewicz 2021; Yossef 2013).

Therefore, the relevance of drawing in design education today is mainly evident in design critiques, which follow the entire work process. It is also important to distinguish the uses because sometimes only the instructor uses drawing. What we argue here is that even in such cases, drawing is beneficial and highly relevant to the teaching process, even if students passively benefit from it.

Another aspect revealed by our research is the need for conceptual clarification and verification in relation to research on freehand drawing, which may partly be related to the methodological shortcomings we previously noted. We found that attributes associated with freehand drawing, such as visual thinking, have little operational value in the context of observational research and may even be detrimental to obtaining useful and verifiable results. While it may be widely accepted that drawing promotes visual thinking, translating this concept into practical research and data analysis is challenging.

As we discussed in the theoretical review, visual thinking, along with visual communication, are two major functions of drawing, within which many other functions can be identified (Vistisen 2015). Furthermore, the distinction between these two functions is not always clear-cut.

Regarding observational drawing, although it is frequently mentioned in the literature as a way to learn how to see, our data show that it is primarily a type of drawing used by those who learn to draw, as in the case of FAUP. Moreover, we see that this type of drawing is

primarily used by these students in their early years when it is part of instructor requests but declines in frequency afterward. This raises the question, as noted by Vaz (2002), of why students should learn this type of drawing if they are rarely going to use it later on.

Lastly, based on our data, we emphasize the importance of drawing serving as an annotation tool, a type of usage with limited expression in the literature but one that we find highly relevant in design studios—as we will explore further, perhaps the most relevant function in today's design studios.

6.4 Why is freehand drawing still used?

6.4.1 Existing literature

Concerning the second research question—why freehand drawing is still used in architectural design teaching?—the literature highlights a set of qualities or characteristics associated with drawing, as well as aspects that drawing promotes, enables, or supports. The values indicated below follow the results of the literature review (see 1.4 Review).

Regarding the qualities or characteristics of drawing, one aspect noted by the literature, although with limited relevance (n=5), is that drawing compresses a wide range of important attributes for design. This is an intriguing aspect that seems to distinguish drawing from other forms of representation. As Yossef and Salama (2013) point out, sketching can serve various purposes, such as recording what the designer observes, capturing an idea, or quickly demonstrating a graphical image, which is why it is extensively used by professional designers. Additionally, Akalin and Sezal (2009, 3) state that sketches are "essential representations for thinking, problem-solving, and communication in the design disciplines." They further emphasize that in an educational context, students learn to think through drawing, develop their ideas, and solve complex problems.

Some authors also link drawing skills to the quality of design (n=4), with students drawing as a factor in enhancing both the design process and the final product, precisely due to the multitude of attributes associated. Putra et al (2022, 8) suggest that in the learning process, "architecture students who engage in manual drawing produce designs of better quality and have better design intuition compared to those who design directly using a computer."

In terms of qualities promoted by drawing, creativity is the most frequently mentioned in literature (n=13). Nørgaard (2017) states that drawing is a tool for fostering idea generation and exploration in a design situation. Alipour and Faizi (2016) argue that sketching can represent a sudden burst of creativity, arising from both analysis and the search for new design solutions. Similarly, Putra et al (2022) highlight the importance of designers

mastering drawing because it fosters unexpected discoveries influenced by sensory and conceptual factors.

One of the most referenced to aspects in the literature is that drawing allows for abstraction or ambiguity in representation (n=9). Akdag (2018) explains that the ambiguity of sketches, contrary to what one might think, is not a negative characteristic but brings new opportunities for positive development. Soygenis, Soygenis, and Erktin (2010) suggest that sketching helps designers' abstract attributes of hypothetical design solutions and summarize their complex patterns. Likewise, Nováková, Achten, and Matějovská (2011) emphasize the importance of mistakes and incompletion permitted by drawing.

Another attribute with some consensus in the literature is that drawing allows expression (n=9). Putra et al (2022, 7) state that "manual drawing is unique because it not only has a personal touch but also reflects the perception that an individual constructs in his/her mind." In this regard, as Şenyapili and Basa (2006) point out, the sensitivity and authenticity that manual drawing enables cannot be challenged by computers, despite all the advances related to digital media. This aspect is particularly relevant in education, as issues of identity and authorship remain significant determinants.

One attribute of drawing is that it enables interaction (n=6), which is especially relevant in the design studio, where the primary pedagogical moment occurs in the relationship between instructors and students. As Eren and Yılmaz (2022) note, the success and efficiency of design education depend on the interaction between instructor and student, facilitated by drawing. Bailey (2021, 4) describes freehand drawing as "a ladder or scaffold that supports the student and allows meaningful critical dialogue between student and master about the design process."

Another attribute mentioned in the literature, although with less emphasis, is that drawing allows for the incorporation of bodily factors into the design process (n=4). As Leandri (2021) points out, bodily involvement is crucial in the architectural design process and should form the basis of mental processes and divergent and creative thinking. In fact, as this author mentions, there is some evidence that "parts of the central nervous system related to movement and proprioception might be linked to creativity" (2021, 5).

The literature also suggests that drawing allows for transformability (n=4), both from a mental and graphic perspective. On one hand, as noted by Eren and Yılmaz (2022), in manual drawing, hand movements are followed by the eyes, establishing a stronger brain-hand coordination. This enables students to internalize drawings through visual and tactile senses, facilitating the creation and manipulation of three-dimensional images in the mind. On the other hand, as Špaček, Peciar, and Šíp (2016) mention, sketches as physical interpretations of a concept or idea have a highly transformative nature.

Furthermore, in terms of qualities, one attribute of drawing that often arises in association with others is speed. Putra et al (2022) mention that the representation of ideas can be rapidly achieved, while Taraszkiewicz (2021) highlights the speed and ease of communication when drawing is used.

6.4.2 Evidence-based observations

Multi-qualities

An argument raised by the literature, although not a dominant one, is that freehand drawing encompasses a wide range of qualities, setting it apart from other more commonly used forms of representation. Some of these qualities are quite straightforward, such as ease of production—at least for certain representation tasks—speed, and a degree of ambiguity, in contrast to more precise forms of representation.

The diversity of drawing qualities, as well as the different functions and types of drawing it enables, are evident in the various categories of our analysis. While it is true that experienced students use drawing more frequently, have access to a wider range of functions such as perspective, and are more adept at using it dynamically, even students without formal training can use drawing in the design studio. It is worth reiterating that in some situations, such as during design critiques, there is no other tool that combines the necessary functions that drawing alone provides.

Creativity

As seen, the argument that drawing promotes creativity is widely accepted in literature. With our data, we can approach the issue of creativity by considering how a representation fosters design moves, which can also be associated with the promotion of exploration, as mentioned in the literature.

What we gather from the recorded data is that there is not a direct correspondence between the use of freehand drawing and the ease of making design moves. What we observe is that design moves are favored when freehand drawing is used in a particular way, i.e. dynamically. Nevertheless, drawing is considered a significant facilitator of design moves by instructors, and it is the most requested form of representation for students to use.

For instance, when a student draws a plan in CAD software, prints it, and then manipulates that representation through annotations, it inherently enhances design moves. This is evident not only during design critiques but also when students encounter difficulties with design fixation, as it is a practice typically recommended by the instructor.

It is important to emphasize, however, that this dynamism is not exclusive to freehand drawing, as physical models also exhibit these characteristics, as seen in the case of FAUP. Additionally, students do not need formal drawing training to use this approach. For example, students at MIT have the capacity to employ design moves through freehand drawing, while those at POLIMI may find it more challenging. Similarly, high-level drawing skills are not necessary for this, as previously noted: even simple annotations can enhance dynamism.

Here, we can relate to another aspect mentioned in the literature, albeit with limited relevance, which is establishing a correlation between drawing skills and design quality. However, "design quality" is a somewhat ambiguous term that, if not specified, could refer to either the final product's design or the design as a process.

Regarding the former, our data does not allow us to determine such a correspondence, and it appears challenging to do so, considering the many variables at play. As previously mentioned, it is not just about the level of drawing proficiency but more about how drawing is used.

However, if we interpret "design quality" in terms of the design process, we can say that our data support this idea. If we consider quality as the student's capacity to smoothly navigate the various stages of the design development, we see that those who use drawing—again, in a dynamic way—encounter fewer difficulties in terms of design fixation, which is the point where representation is directly related to the design.

Interaction

The issue of interaction, or the fact that drawing complements verbal communication, although not highly emphasized in the literature, is, according to the data from this study, one of the most determining factors for the continued use of drawing in design teaching.

As evident from the data presented, especially in the context of design critiques, where interaction is a fundamental aspect of project pedagogy, we can see that drawing is the most commonly used mode of interaction between instructors and students, second only to speech and gestures. Interestingly, this occurs in all three schools, and despite variations in the frequency of drawing use, even students without formal training use it. We also observe that there is no substitute with the same possibilities for interactivity as drawing, whether analog or digital.

We also noted that during the pandemic period, one of the most limiting aspects in the initial remote classes was the absence of this interactive dimension in design critiques, both between instructors and students and among their representations. This need was so apparent that both quickly adapted and began to use digital drawing, in many cases using

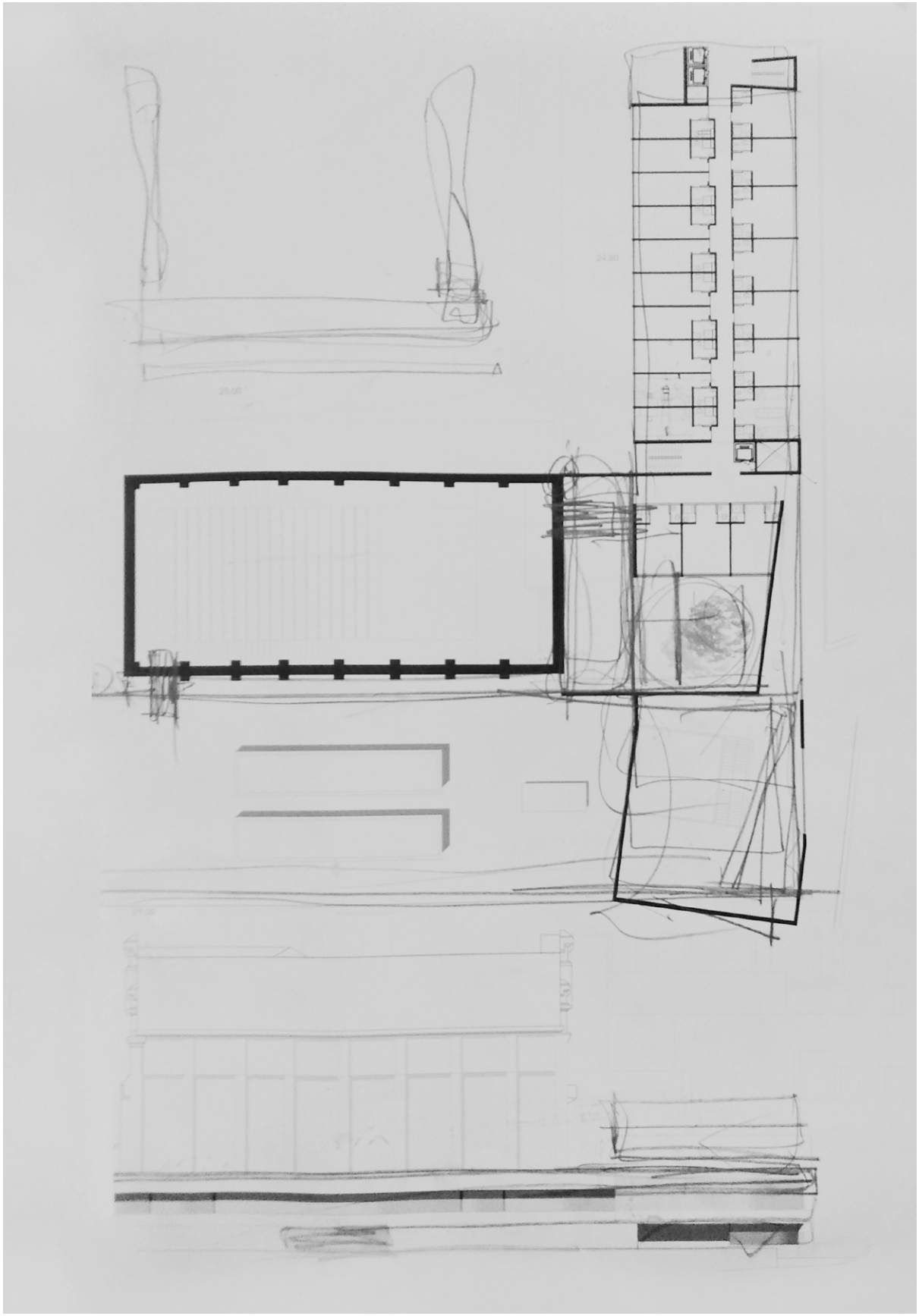


Figure 77. Student's annotations on her own work, FAUP, 2021

their computer mouse, a tool less suited to and suitable for the task, to interact with the representations presented during the critiques.

Manipulation

It seems that here, interaction can be associated with enabling transformation and manipulation, which is also mentioned in the literature as these aspects appear to be closely related. If we primarily consider interaction as a form of communication or collaboration between instructors and students, the manipulation and transformability of drawings can occur during this interaction or as part of an individual student's process.

This manipulation and transformability also seem to promote design moves and can be achieved through the aforementioned annotations or, for example, by overlaying drawings directly or using tracing paper. We observe that in the case of students from FAUP and POLIMI, students primarily use their own representations (figure 77) or tracing paper as a support, and correspondingly, they have fewer difficulties with design fixation. It is a simple way to transform a representation by adding new information to it.

An important aspect to consider is that even when students do not draw and experience issues with design fixation, these difficulties are often overcome during design critiques. In other words, if a student struggles to use the representation dynamically, the instructor applies this dynamism during design critiques through interaction or manipulation, thus enhancing design moves for the student. This is an intriguing aspect that allows us to conclude that even when a student does not draw, they benefit from the attributes of drawing through the instructor.

Perception

There are several arguments in the literature, not necessarily explaining why drawing continues to be present in design teaching, but rather related to the teaching of drawing itself. One of these arguments is that freehand drawing allows for sensory perception, which is associated with what we discussed earlier regarding observational drawing.

Although this aspect is evident in a school like FAUP, where students learn to draw through observation and incorporate this knowledge into the design studio, it is nearly absent in the other two schools where drawing is also frequently used. We can consider this aspect more as a particularity of FAUP rather than a reason why drawing continues to be present. While it is indeed a "unique" quality of drawing, it does not appear to be "necessary" for the design process in general.

On the other hand, in the literature, mastery of drawing through teaching and practice is mentioned as a prerequisite for using digital tools effectively. What our data reveals is that

one of the challenges faced by students who do not have proficiency in freehand drawing is understanding and representing perspective, or in other words, having a practical-intuitive application of geometry. In this regard, symmetrically, we observe that students who learn drawing encounter fewer difficulties in terms of perspective, with FAUP students producing significantly more perspectives than those in the other two schools.

6.4.3 Implications for research

The argument that freehand drawing itself possesses numerous qualities for design is a strong argument with some support from the literature regarding why drawing continues to be used in design studios (Goldschmidt 1991). We emphasize, following the distinction made in the previous point, that we are referring specifically to design teaching, where drawing is essential for both the design process (individual) and, especially, for the teaching process (collective).

This is an important clarification to make because, regardless of the relevance freehand drawing may have in professional practice, which we are not considering here, its role as a didactic tool appears to be evident. Not only do our data confirm the significance of freehand drawing in design teaching, examining the various uses and functions attributed to drawing, but they also demonstrate that it is unique in the multitude of qualities it possesses and enables. In this aspect, we find that there is no equivalent representation tool.

On the other hand, what our data show, and perhaps most importantly, is that drawing does not seem to have a substitute that allows for the same uses in design critiques. From the data, we observe that drawing is the most frequently used form of interaction by instructors in all three schools, as well as by students, regardless of their background.

If we were to remove drawing from the current scenario, we would see that there is no alternative form of representation. Consequently, critiques might be reduced to verbal and gestural interactions, as observed in some cases. We also note the great importance of this interaction, which became evident during the pandemic period when, out of necessity, drawing shifted to a digital environment. However, it is important to emphasize that it remained freehand drawing, using the same technique but in a different medium.

We also observe, and this is an important aspect, that even students who do not draw in design critiques benefit significantly from the instructor's drawing. Whether it is for initiating design moves, a common challenge among students—some of whom wait for the instructor's guidance to overcome this difficulty—or for explaining complex information succinctly, providing a reference, demonstrating, or exemplifying (Cabau 2016).

This allows us to consider that the fact that a large number of instructors continue to draw—and nearly all of them received training in drawing—has enabled the fundamental approach of the design critiques model to continue functioning, despite the significant transformations driven by the development of new digital tools (Dorta et al 2016). An exercise to consider, looking ahead to the future of design teaching, is what will happen when generations of instructors who learned to draw are replaced by instructors who did not learn to draw and are less inclined to actively use drawing. At that moment, more pronounced transformations may occur, and a certain coherence or connection to the tradition of the design studio model could change significantly.

Moving on to the question of creativity, which much of the literature directly associates with drawing, we must once again, in light of our observation data, be precise and operational. We do not find a direct correspondence between the use of drawing and creativity in design, assuming creativity here refers to design moves. What we observe is that, depending on how drawing is used, especially when done dynamically (Goldschmidt 2014), it can be highly conducive to design moves.

In essence, drawing has various attributes that favor creativity, as we have seen earlier, but it still requires a specific mode of use. Garner (2012) draws a parallel between drawing and writing to explain how the act of drawing itself promotes the emergence of unexpected ideas, as well as fluent and inspired mental flow—which aligns with Goldschmidt (1991) and Tversky (2015). The author associates these attributes of drawing, much like in writing, with the active and significant involvement of the hand, gestures, and even the body in the process.

Goldschmidt (1991) also defines freehand drawing as a common human activity, much like writing, as do Norgaard (2017) and Bilda and Gero (2006). This relationship between drawing and writing finds acceptance among various authors, although it appears more as a metaphor than an operative parallel.

As we have seen earlier, the issue of the body's participation in drawing, and by extension, in design, has been emphasized by several authors. Interestingly, as we observed in the case of MIT's historical evolution, two important arguments for the continued use of drawing, even as it began to seem outdated, were, on one hand, drawing's ability to train careful observation—something photography could never achieve—and, on the other hand, bringing the body into higher education, which tended to be primarily intellectual (see 5.5 Drawing as a historical record). This underscores the mind-body relationship, which is still the motto of MIT, *mens et manus* (mind and hands).

Although several authors support this perspective, we see that it is a less explored topic in research or scientific literature and is more addressed through essayistic approaches, as in the famous book The Thinking Hand (1994).

Finally, let us regard the argument of freehand drawing as a propaedeutic, which finds some support in the literature. As Eren and Yılmaz (2022) mention, it is absolutely necessary for students to begin expressing themselves using hand drawing before transitioning to digital media.

The same argument is used by instructors at FAUP, both in drawing and design, where drawing is seen as important for introducing representation issues. Associated with this argument is the fact that mandatory and widespread drawing education serves as a way to address the significant diversity of backgrounds students come from, resulting from various educational paths—whether they have followed artistic, humanities, or scientific courses.

As Pause (1976, 144) refers, "the first issue of teaching the design studio is the range of diversity of the students relative to interests, objectives, skills, perceptions, etc., present in a studio." This issue arises primarily in the first year and is also a concern raised by first-year instructors at POLIMI.

Here, a clarification that is not always evident in the literature is the curricular framework of this drawing education. We can talk about a model where there is formal drawing education with courses independent of design projects, or drawing could simply be encouraged for use within the design studio—something we observe at FAUP and in some courses at POLIMI, both in drawing and physical modeling.

Thus, in the case of FAUP, there is a concerted alignment for teaching and implementing drawing in the design studio. Students learn to draw in drawing courses, and in the design studio of the same years, they are encouraged to use drawing throughout the teaching process.

Regarding the formal aspect of drawing education, FAUP students who undergo this training develop strong drawing representation skills, observational drawing skills, and knowledge of perspective and geometry, which is reflected in their design process drawings. In contrast, we observe that students from other schools who do not have this training generally struggle with geometric understanding and producing perspectives, unless they are supported by software tools.

6.5 How could freehand drawing be used?

6.5.1 Existing literature

Regarding the third research question—how could freehand drawing be used in architectural design teaching?—existing literature provides a set of recommendations which can be organized into improvements or new approaches for (i) design

representations, (ii) design teaching, or (iii) drawing education. The values indicated below follow the results of the literature review (see 1.4 Review).

Starting with design representations, one of the recommendations with significant prominence in literature is improving the relationships between freehand drawing and other manual instruments with digital tools (n=7). As Putra et al (2022) suggest, the complexity of designing activities requires the combined use of computers and sketching, exploring their collaborative possibilities. Špaček, Peciar, and Šíp (2016) mention the example of several students who struggled to develop an idea because the software they were using did not allow it, without realizing they could resort to freehand drawing.

In this context, Taraszkiewicz (2021) points out that even when students learn to draw, as well as when they learn other forms of representation, it is not common for them to have a course that teaches them how to use these skills in the design process, at what stage, or which tool is most appropriate for a specific design problem. Therefore, as Nováková, Achten, and Matějovská (2011) argue, considering the advantages of freehand drawing in the design process, especially in design teaching, such as creative visual thinking and visual communication, an optimal fusion with CAD systems, whether classical or parametric, is fundamental.

Still regarding design representations and related to the previous recommendation, a significant part of the literature also suggests the incorporation of digital drawing into design teaching (n=6). Leandri (2021) mentions that a shift is needed away from outdated notions of "hand graphics" and "rendering" towards less rigid and more accessible forms of freehand drawing that incorporate the best of digital technologies. As the author states, digital freehand drawing is now possible through the use of tablets or software for faster and vector-based graphics, which have seen significant advancements in recent years, with cost no longer being a major issue.

Akdag (2018) also notes that digital tablets differ greatly from conventional computers, both in terms of mobility and drawing precision, pressure sensitivity, and user-friendly applications. Therefore, similar to what has been observed in practice, their integration into design education is a challenge and a concern that deserves attention. Akdag (2018) further suggests that surveys with students indicate that it may still be too early for them to completely abandon pen and paper, so hybrid drawings and techniques, combining the advantages of both media, might be the most viable option.

Another domain where digital drawing is mentioned involves not only its use as a representation tool but actively integrating it into the design process (n=3). Bailey (2021) presents a study that analyzes design critiques, discourse patterns followed by students and instructors, the role of sketching in this discourse, and the possibility of integrating digital sketching as a means of supporting communication. The results indicate that while

sketching is the most efficient and effective interface for students to access design information, it can sometimes be too passive in its iterative role. In this aspect, digital drawing can be beneficial. One argument used is that students tend to be inclined towards new technologies, making it an engaging option.

Hsu et al (2020) take this idea further by testing the use of digital drawing in design critiques, but in a Virtual Reality (VR) environment. As the authors mention, this system is expected to allow participants to navigate and visualize architectural models on a human scale, enabling more direct interaction and reducing mental effort. For the VR tool proposed by Hsu et al, students and instructors can engage in mid-air sketching and on-surface sketching in a virtual environment. Here as well, it is noted that this approach seems to favor direct student engagement with design critiques.

The last group of recommendations, revolves around improving or adopting new approaches to teaching drawing. One of the suggestions made by Putra et al (2022) is the integration of information technology, especially social media, to capture students' interest. On the other hand, also capitalizing on students' affinity for digital media, Domínguez and Roma (2010) present an experience of integrating digital drawing into drawing courses, exploring the combination of analog and digital tools. As Domínguez and Roma (2010) state, the approach involves the use of Sketch-Based Interface and Modeling (SBIM) methodologies, which the authors define as digital freehand drawing. These methodologies are well developed in the field of engineering but not as much in architecture.

Finally, we consider a new approach proposed by Nørgaard (2017) to teaching drawing. As the author mentions, recognizing the impact of the lack of basic knowledge in drawing on his students' learning experience in design, he decided to find a basic form of drawing education, which he called "sketchnotes." According to the author, sketchnotes are "hand-drawn visualizations made on paper or tablet, created within a short time frame" (2017, 8). It is based on instructing some basic sketching principles that allow students to create visual annotations and use drawing for analysis and presentation. In this way, students "learn to identify which qualities add to the value of a sketch note and get help identifying their own development areas. These qualities and techniques are highly relevant for their successful work with design sketching in the future" (2017, 8).

6.5.2 Evidence-based observations

Relating freehand drawing with other forms of representation

Various proposals highlight the added value of strengthening the relationship between freehand drawing and other forms of representation, especially digital tools. In current

design studios, these types of intersections already occur, sometimes spontaneously or intuitively, and in other cases, deliberately promoted by instructors, as our data shows.

A common scenario involving the interchange of different representation methods can be described as follows: a student uses freehand drawing to outline a general proposal, then draws the proposal accurately using CAD software, prints the design on a large-format sheet, and subsequently use freehand drawing to manipulate and transform the proposal. This description could continue with the student using tracing paper to define a variant of the proposal, returning to draw it accurately in CAD software, or even starting a 3D model, possibly followed by another printing step.

As our data indicates, even students who do not learn to draw tend to use freehand drawing, either in simple operations like the one described earlier or as support for design critiques. However, many students do not engage in this practice, and while a significant percentage of students use drawing, a substantial part does not.

In the previously described work process, it is evident that many students exclude freehand drawing from their workflow, choosing, for example, to work exclusively with CAD software or combining it with 3D modeling software. This can lead to issues like design fixation, and for such functions, high-level skills or even basic drawing training are not required.

A curious aspect raised by Akdag (2018) is that students who use freehand drawing in the design process tend to avoid it during critiques with instructors. The author suggests that they often prefer not to expose their work to peers or instructors and tend to verbally explain their projects instead of using drawing.

In this context, it would be beneficial for students to be aware of the available possibilities and the resources offered by freehand drawing, which, in reality, require very little from them to achieve significant results. On the other hand, even students with training in drawing, as seen in the case of FAUP, tend to "forget" what they have learned previously and may not recall the skills and knowledge they have acquired, especially when it comes to integrating digital tools.

Conventional and digital freehand drawing

In several proposals presented in the literature, there is frequent mention of digital drawing, whether for its integration as a form of representation in design teaching, as an educational tool, or as an enhancement of traditional drawing education where such courses exist. It is clear that in literature, the future of freehand drawing will necessarily involve a digital migration or, at the very least, digital possibilities will be explored due to their associated potential.

Throughout this work, several references have been made to digital drawing. In one of the schools, MIT, digital drawing already holds some significance, where students use it exactly like traditional drawing but with devices such as tablets, e-readers, or laptops with touchscreens. These digital supports replace traditional notebooks and serve both for drawing and writing, such as taking notes during lectures.

In this way of using digital drawing, the only thing that appears to change is the interface. In terms of device response, drawing possibilities, and technical application, it is largely similar to traditional drawing, enriched by the possibilities of digital interaction. For instance, students can use a PDF or an image as a base for drawing, or they can leverage the extensive transformability offered by digital tools, including a variety of brushes, colors, line editing, layers, and more. The drawings are directly converted into vector format, which is then used in design critiques and the students' own project work.

On the other hand, we have seen in this work how digital drawing emerged out of necessity during the pandemic period, replicating the interactivity of traditional drawing in a remote learning environment. Students shared their work, which ranged from manually created drawings to CAD drawings, 3D models, or photographs of physical models, on their desktops. This initiated an interaction between them and the instructor, both using digital drawing as a mode of interaction. Despite the challenges posed by the pandemic emergency, this use of digital drawing ensured that a central aspect of the pedagogical approach to design studio education was not lost. Moreover, it opened up several new possibilities by combining analog and digital environments, such as instructors directly interacting with CAD or BIM files under construction while simultaneously using digital drawing software.

We also observed that at FAUP, the teaching of drawing continued in the same way as design studios, with instructors discussing and interacting with students' work in a digital environment.

In conclusion, our data indicates that the key attributes of freehand drawing are not compromised when transitioning to a digital environment, and the same skills from traditional drawing can be transferred seamlessly. Simultaneously, numerous new possibilities related to representation, design teaching, and even drawing instruction can emerge. Based on the observations made, it appears that digital drawing could indeed be a prospective direction for the future.

Students' interest

One clear theme in the proposals presented in the literature is that the recommendations aim to align with students' interests, recognizing that this alignment is crucial for the success of any of these improvements or new approaches. As we have observed, literature

underscores the significance of student interest. In many respects, one of the challenges in education— not only in teaching drawing but also in architectural education and education in general— is to convey to students the relevance of freehand drawing, enabling them to recognize its utility and engage in the learning process (Pais 2018).

For instance, in the case of FAUP, we see that students who learn freehand drawing in mandatory courses and apply it in corresponding design studios tend to gradually discontinue its use in subsequent years. Similarly, even during the first two years of study, it is common for some students to bypass the rules and use digital tools.

This highlights that a substantial part of students may not perceive the importance of freehand drawing. Some, as mentioned by Eren and Yılmaz (2022), view these techniques as a waste of time, while others, as stated by Leandri (2021), find the process challenging and arduous. It is evident that any recommendations or improvements related to freehand drawing in education must be designed to capture and sustain student interest, addressing the perceptions and concerns they may have regarding its relevance and value.

6.5.3 Future perspectives

Before delving into perspectives on how to use drawing in the future, specifically how its use in the context of design teaching could be enhanced, three preliminary points should be addressed: (i) the significance of representation in education; (ii) why it is worthwhile to persist in freehand drawing; and (iii) how to proceed in such direction.

Why is representation relevant?

The first point concerns representation in design teaching, which essentially forms the basis for the relevance of our analysis and the proposals we will make for the future. As we have already seen, the designer's activity, or designing, is closely linked to representation, to the extent that Visser (2006) defines designing as the creation of internal and external representations. Similarly, Milovanovic (2019) states that the design process unfolds through the interaction between representations.

However, as we have also emphasized, it is essential to distinguish between design and design education. In this context, in line with Şenyapili and Basa (2006), it appears that in design education, and especially in design critiques, the importance of representation is even greater compared to professional practice. On one hand, representation defines the designer's activity itself, serving as a fundamental element of support in all aspects of the design process. On the other hand, in design education, representation plays an even more crucial role.

As noted by Milovanovic (2019), the set of representations produced by the student is a key element for design critiques, as the interaction between instructor and student—the essential dynamic of the educational approach in design teaching (Goldschmidt 2014)—emerges from these representations. However, the representations produced during design critiques, whether by instructors or students, themselves hold significant importance throughout the teaching process (Leandri 2021).

This significance is evident from our data, including those illustrating the percentage of representational actions during design critiques in all three schools. As Lisboa (1998) notes, in architecture, methods and content are inseparable and interdependent, work processes are conditioned by the tools used, and design capability largely resides in technical competence.

Why focus on freehand drawing?

From this first discussed point, we now move on to the second, which concerns the reason to continue emphasizing the importance of drawing in the design studio, to the extent of anticipating its future possibilities. After all, as we have observed, despite a significant part of literature emphasizing its importance, there is also a trend towards its disappearance. As Have and Toorn (2012) note, in various schools, the teaching of drawing has been removed from the curriculum in recent decades.

However, our data demonstrates that even in schools where drawing is no longer taught, it continues to be present in the design studio. As we saw previously, the use of drawing plays a significant role in the students' design process, aligning with literature that commonly links drawing early phases of a design project (Purcell and Gero 1998). Often used in a purely intuitive way, its importance is particularly related to design critiques.

It is worth noting that we consider both the drawings of students and instructors. Even in cases where students do not draw, freehand drawing remains relevant due to the role instructors assign to it. It functions as both a didactic instrument and a co-design instrument, directly contributing to the development of the student's design.

Furthermore, we observe that among the representational actions taken by instructors, complementing verbal and gestural communication, freehand drawings are the majority. We also find that when instructors provide suggestions to students to advance in their design development or address specific challenges, such as design fixation, requesting a new drawing is the most frequent recommendation.

These are some of the reasons to consider that, regardless of a trend toward devaluing drawing and assigning it a completely peripheral role in design teaching, and despite the dismantling of formal drawing courses, the use of drawing continues to be highly relevant

from an educational standpoint in the considered case studies. If this relevance persists, and if we find that despite a progressive devaluation, drawing still plays an irreplaceable role in certain functions to date, it should continue to be taken into account, at least in the near future of design teaching.

What is the context of freehand drawing?

From this point, we move on to the third preliminary point, which concerns how drawing should be considered and integrated into design teaching. This seems to be a highly relevant point to emphasize that there are no generalized approaches that are not directly related to a specific context.

In the three schools we considered in this study, the question of the curricular context is evident. For example, looking at the curriculum of FAUP, we see how drawing and its formal teaching are part of a pedagogical strategy that goes beyond the drawing courses themselves but is directly related to the corresponding years' design studios and indirectly connected to other courses. Within the courses themselves, we can see how the didactics reflect these assumptions, and even in the design studios, the teaching process significantly relies on drawing, both as a design tool and a teaching tool. Thus, especially in the first two years of FAUP, the strategy is to provide students with a common background and skills, equipping them all with the same tools before they pursue their preferred directions.

On the other hand, in the case of MIT, the strategy is radically different. Instead of seeking to build a fundamental uniformity among students, they aim to explore diversity among them. For this reason, we observe within the same class a variety of approaches and forms of representation and production, ranging from the use of traditional tools like drawing to the production of prototypes in concrete, metal, or plastic, and even the use of highly complex parametric digital tools.

This contextual difference shows that a direct migration between approaches of these schools would be unfeasible and even undesirable. Rather, in each of these situations, it is essential to identify potential strengths and weaknesses and seek to enhance the former while mitigating or addressing the latter. For instance, the fact that freehand drawing continues to be taught in mandatory two-year courses at FAUP, and we observe positive results among students and in the pedagogy, does not mean that the same approach would make sense at MIT at this time.

In fact, our study on the history of the MIT Department of Architecture reveals that curricular transformations have historical reasons, although it is not always possible to identify the transformative agents or be certain of them. Nevertheless, there is a historical development associated with each curriculum plan and school. Just as we saw at MIT, we

could make a similar assessment for FAUP (Fernandes 2010) or POLIMI (Brighenti 2018), understanding how these institutions evolved over time.

Three perspectives for freehand drawing

Regarding future perspectives for the use of drawing, existing literature primarily emphasizes the need to find ways to bridge freehand drawing with digital technologies. This can be achieved through a hybrid analog-digital approach or a shift towards digital drawing, as we have seen, including the integration of VR technologies.

There is a general trend towards digitalization, a phenomenon that cuts across various disciplinary and professional fields. In the realm of design, especially in design teaching, where representation holds significant importance, a large-scale transition like the one driven by information technologies has a profound impact. As previously discussed, the introduction of laptops into design studios, according to Dorta et al (2016), brought about significant transformations in traditional pedagogical approaches. One consequence of the increasing emphasis on digital tools seems to be, in some cases, the corresponding devaluation of freehand drawing.

Our data have shown that the situation is not entirely negative for freehand drawing since it continues to be used, even in schools where students no longer learn to draw. At MIT, for instance, we observed that part of this drawing has migrated to the digital environment, with many students drawing on tablets, e-readers, and laptops. As mentioned earlier, this may be because most instructors in these schools received training in freehand drawing and continue to apply it in design studios. Predicting what will happen with the new generations is more challenging.

The proposals from the literature are grounded in recognizing the importance of the attributes of freehand drawing in design teaching and its enhancement through digital resources. It seems that this path is not just an option for improvement but a necessary change to ensure the continued relevance of freehand drawing in design studios, preserving its associated techniques and qualities.

The perspectives presented here are organized into three categories, which we refer to as the (i) consolidation perspective, (ii) transition perspective, and (iii) training perspective. These perspectives are closely related and complementary, and as we will see, none of them implies structural transformations either to the pedagogical model of the design studio or to the specific use of freehand drawing in an educational context. They are based on the knowledge obtained from the case studies and existing literature but are not directed at the schools we analyzed. These should be seen as directions for future research and experimentation.

Consolidation perspective

The consolidation perspective focuses on strengthening and highlighting the role of freehand drawing in architectural design teaching. In this context, it is not about introducing entirely new elements into existing processes, but rather recognizing aspects that can be emphasized, enhanced, or mitigated.

Our data shows that in many cases, the presence of freehand drawing in design studios is sporadic and lacks systematic integration. Often, its use depends on individual student preferences. For instance, even in schools like FAUP, where drawing is taught, students progressively reduce their active reliance in subsequent years. They sometimes even stop using it for basic tasks that would not necessarily require advanced skills.

While the lack of formal training in drawing can be a factor contributing to students' limited engagement with it, as we will discuss later, it may not be the most significant cause. Our observations suggest that one key issue is the students' lack of interest. Some students perceive freehand drawing as a demanding and time-consuming technique, and they question its relevance to their future professional activities. Another aspect on which this integration perspective is based is the lack of clear and explicit guidance from instructors, not necessarily advocating freehand drawing as the primary design tool but as an intermediary instrument—this nuance appears to be significant.

With this perspective, our goal is not to place freehand drawing at the forefront of design studios but to strengthen and systematize its role as a supportive or complementary tool, which is its current position. The significance of drawing in the design studio lies in its support for various pedagogical activities, whether from the student's perspective in their individual work process or in the interaction between students and instructors. These attributes, as mentioned earlier, which appear to be unique to freehand drawing, should be acknowledged and emphasized. These attributes include exploration and manipulation (linked to visual thinking) and interaction (linked to visual communication).

What we emphasize with this perspective is the importance of instructors explicitly highlighting, on one hand, the most relevant components of design teaching and, on the other hand, how drawing can support these components. One of the most crucial aspects, even in consideration of students' interests, is recognizing that freehand drawing can play a significant role when combined with other forms of representation, especially digital ones, serving as a meta tool.

An example of this was seen at POLIMI when an instructor suggested to a group of students that they print visualizations of their design proposal created with BIM software. They were then encouraged to use freehand drawing to explore modifications and variations to the original form. This suggestion arose in response to the students' struggles with design

fixation. Importantly, this approach does not limit students without drawing backgrounds because, by working on a stable geometric base, they can address perspective production issues. It also demonstrates the specific benefits of drawing with the software they were using, addressing a particular difficulty.

These practical demonstrations of how drawing can be used to solve specific problems, without requiring extensive effort or advanced skills, as well as its potential when combined with sophisticated digital tools, while seemingly straightforward, can have a highly beneficial impact on students' education, which is ultimately the most critical aspect to consider here.

Transition perspective

In continuation of the previous perspective, for the consolidation of the complementary role of freehand drawing in design teaching, we now highlight the possibilities of transitioning this freehand drawing into a digital environment. This is not a new hypothesis but rather a dimension associated with the assumptions of the previous perspective.

As we have mentioned before, based on our observations, the conventional-digital freehand drawing dichotomy does not seem to have a negative impact on its attributes and functions, compromising them. In fact, the data suggest opportunities for enhancing freehand drawing through digital transition.

As we have pointed out on several occasions, this was first evidenced during the pandemic period and the necessity of shifting to online teaching. Due to the essential attributes of freehand drawing, which were demonstrated to be irreplaceable in design critiques, there was a migration of drawn interaction and manipulation to the digital environment. Despite this transition occurring out of necessity, without prior preparation, and in many cases with very limited resources—as we have seen, a significant portion of this digital drawing was done with a regular computer mouse—it revealed significant potential, especially when combined with other forms of representation, both analog and digital.

We were particularly impressed by the capacity to interact with freehand drawing in working files, in CAD or BIM software, enabling rapid, easy, and flexible manipulation of the base information in a hybrid design composition process. This also extends to co-design and pedagogical monitoring, where instructors have the opportunity to participate more directly in the student's work process and provide guidance. Just like its conventional counterpart, digital freehand drawing is inherently a meta-tool.

On the other hand, observations at MIT demonstrated that digital drawing using tablets, e-readers, or laptops is already a common *ad hoc* practice among students. They use this interface not only for drawing but also for taking written notes, essentially treating it as a

digital notebook. Furthermore, in several design studios at MIT, class critiques take place in a digital environment through platforms like MIRO, facilitating the participation of the entire class, as students can interact directly with their peers' work using their individual devices.

The perspective we emphasize here aims to reinforce the consolidation of freehand drawing in the design studio, as discussed in the previous point, through a digital transition that can initially be partial. It involves understanding the lessons brought about by the inevitability of the pandemic period, as well as the experiences already conducted in other schools, and applying them to in-person design classes.

As the literature suggests, bringing freehand drawing closer to the digital realm seems to be a condition for its survival, finding a way to transfer its essential attributes into contemporary design practices, and, we would add, enhancing these attributes through digital possibilities. This appears to be a very promising avenue for future research.

Training perspective

The third perspective relies on providing elementary training for students without a background in freehand drawing, which can be seen as a form of basic drawing literacy. One aspect we have observed with our data is that even students without formal drawing training are capable of using it in the design studio, both as part of the design process and in design critiques. However, only a portion of students engage in this practice, and even those could benefit from more effective use of drawing through basic drawing education.

This training would not only be useful for refining and enhancing the dynamic use of drawing as an essential complementary tool for making design moves but also for fostering an extensive investment in graphic annotations. Additionally, this basic training could equip students with skills in understanding perspective representation, thus developing an intuitive grasp of geometry and improving their manual drawing proficiency.

As we have seen, a strengthened understanding of perspective and applied geometry is a valuable attribute not only for spatial comprehension but also for representation and, by extension, projection, or composition. This knowledge is also beneficial for the types of digital productions students can create. Moreover, improved manual drawing skills could make students more comfortable with freehand drawing, both in the design process and, especially, during design critiques. As we have noted, many students tend to avoid using drawing in design critiques and rely exclusively on verbal discussion (Nørgaard 2017).

The perspective of providing fundamental drawing training aligns with proposals found in existing literature regarding sketchnotes (Nørgaard 2017). These foundational drawing principles applied to design could be integrated as a module within design studios, similar

to CAD modules, as seen at POLIMI. In fact, the mode of freehand drawing could be succeeded by CAD and BIM modules. This would be a relatively minor change in curriculum organization but one we believe would offer significant benefits to students, directly in the design process and throughout the pedagogical process by improving their relationship with instructors. The concept of sketchnotes is fully compatible with digital drawing, which could be a positive factor in attracting students to embrace this approach.

Chapter 7 Conclusion

7.1 Overview

Architectural education, particularly design teaching, has experienced significant changes in recent decades due to the impact of digital media. These changes have raised questions about the relevance of traditional forms of representation, including freehand drawing. Despite the importance attributed to freehand drawing in literature, especially in educational contexts, it has been gradually removed from the architecture curriculum. Additionally, our bibliometric analysis (see 1.1.2 Relevance) revealed that research produced since 2000 related to freehand drawing has had little significance compared to other topics in the field of representation, particularly digital media.

The purpose of this research was to assess the relevance of freehand drawing in design education, recognizing how freehand drawing is currently used (RQ1), identifying the reasons for its continued presence in design teaching (RQ2), and proposing future perspectives for its use (RQ3). The three research questions were initially explored through a systematic literature review (see 1.5 Review). Knowing the stances presented in the literature was crucial not only at the beginning of this research, preceding data collection, but also during its analysis and discussion. As mentioned by Merriam (2009), conducting literature reviews at various stages throughout the research process is highly advisable.

Through this literature review, we identified the key research issues concerning the topic of freehand drawing, such as the relationship between digital representation media and traditional, or emerging methods of teaching drawing. We also recognized the most widely used bibliography in the literature, which validated some of our selections and prompted us to include others.

However, one of the most relevant aspects of the systematic literature review, was the identification of the methodological procedures followed. We began by examining the type of evidence used, the most common approach and design, as well as the methods of data collection and analysis. What we realized, and as emphasized several times throughout this thesis, is that there is a methodological gap in the research conducted in our topic. Many studies failed to clearly describe their methodologies, with some not even referencing the procedures they followed. Furthermore, a considerable portion (35%) of these studies drew conclusions without the support of empirical evidence.

In this research, we conducted an evidence-based QUAL study, using naturalistic and participatory observation methods across three case studies: POLIMI, FAUP, and MIT. Raw

field notes were recorded during design classes at these three schools from 2019 to 2022. These notes were then transcribed into a digital format, supplemented by photographs and documentary records. The collected data were organized in a database and subjected to thematic analysis, employing Atlas.ti and Microsoft Excel (see Appendix 2).

Especially due to the lack of former referential studies it was important to define both a theoretical and a methodological framework for this research. Engaging with peers and soliciting feedback through seminars, conferences, and workshops proved indispensable in bridging this gap and keeping abreast of the latest developments in the field, but also offered valuable insights for refining the approach and methodological procedures, which were especially important in our context.

As we discussed, the evidence we gathered enabled us to draw conclusions that had not yet been adequately addressed in the existing literature, and in some cases, challenging prevailing views. For example, it was noticed that freehand drawing is not only prevalent in all three schools under study but it is also a valuable design tool for students, even those without formal training in hand drawing. Surprisingly, freehand drawing plays a pivotal role in design critiques at all three schools, with instructors primarily using it as their mode of interaction with students, without a comparable alternative. Our data also revealed that freehand drawing is present throughout all phases of students' design process, from early stages to advanced detailing. This challenges the prevailing notion in literature that associates freehand drawing primarily with the initial steps of design.

The common distinction between analog and digital, particularly concerning conventional freehand drawing and digital methods, it is not entirely accurate. Our research shows that these approaches are closely interconnected. During the pandemic, for example, we observed how instructors and students seamlessly transitioned to using digital supports for freehand drawing. In the case of MIT, students employed tablets and e-readers for taking notes and creating drawings, mimicking a traditional notebook format. This transition does not fundamentally alter the freehand drawing technique, highlighting the integration of analog and digital methods.

It is important to emphasize that the results we present were only possible through the direct observation of different case studies, during extended periods of fieldwork, and carried out systematically, both in the collection procedures and also in the analysis. This allowed us to reduce biases and our preconceived ideas. Recognizing the pivotal role of the researcher in this kind of QUAL study, which heavily relies on their competence and integrity, as noted by Yin (1984), it is imperative to maintain a high level of systematic rigor in both data collection and analysis. Additionally, it is essential to ensure transparency and provide detailed descriptions of the methodology employed. These aspects are significant

for guaranteeing the quality and reliability of QUAL research and facilitating the transferability of findings to similar contexts.

Reflecting on the current research in architecture, Pelsmakers (in Sousa Santos 2023) emphasized in a recent interview that its relevance hinges on delving deep into issues rather than skimming the surface, and on upholding high standards of quality. This emphasis is rooted in the understanding that research must meet rigorous standards to be fruitful.

With this research, our aim was to examine the current relevance of freehand drawing in the context of design education. We found that despite an apparent decline in interest, freehand drawing continues to maintain a significant presence, even in schools where it is no longer included in the curriculum. Its persistence as both a design tool and a mode of interaction, coupled with the absence of an equally effective alternative in educational settings, underscores the importance of considering it in research. It calls for an in-depth examination of the processes associated with freehand drawing, which we have only broadly considered in this study. Such research is crucial for optimizing the teaching and learning processes in design, which form the core of architectural education.

7.2 Contributions

From an empirical standpoint, this research made a relevant contribution by systematically collecting and analyzing data to address the three research questions. Through this approach, we were able to uncover specific aspects and subtleties that had not been previously identified in the literature. In some cases, we even questioned prevailing viewpoints. Following the principle of transparency in the procedures we have already mentioned, all the collected data are detailed in the appendices of this thesis (see Appendix 1, 2, and 3).

Concerning how freehand drawing is employed in design education (RQ1), our findings reveal that it serves not only as a design tool but is integral to the very core of design education, aligning with existing literature (Purcell and Gero 1998). Our observations indicate that freehand drawing plays a vital role in design critiques across all three schools, used by instructors as their primary means of interaction with students. Instructors recognize its significance in helping students overcome design fixation, employing freehand drawing as a didactic tool.

Our data also highlight aspects not explicitly mentioned in the existing literature, such as the fact that students without formal drawing instruction are able to use freehand drawing dynamically, enabling design moves. Additionally, the fact that drawing is used by students in all phases of the design process, contrary to what is often referred to in the literature, where drawing would mainly be used in the early phases.

Regarding the functions of freehand drawing, our conceptual clarification emphasized its role in visual thinking. Additional identified functions encompassed visualization, communication, and annotation, with observation notably significant at FAUP.

Concerning the reasons for the ongoing prevalence of freehand drawing in design education (RQ2), a well-supported argument from the literature highlights the numerous qualities associated with it, crucial for both the design process and teaching. It is evident that no other representation tool encompasses these attributes. For example, we have observed that in situations where freehand drawing is not employed, critiques are confined to verbal and gestural interactions.

The significance of freehand drawing in the interaction between instructors and students also became evident during the period of the pandemic and the shift to online teaching. Driven by circumstances, there was a transition to digital tools while still preserving the same technique, exemplifying a form of digital freehand drawing. This highlights that the interactive nature of design critiques, a fundamental element of design education, is upheld by freehand drawing.

An important finding of this research is that even students who do not actively resort to freehand drawing benefit from instructors' drawings during design critiques. These instances frequently help students overcome design fixation issues through drawing. This subtle aspect underscores that instructors' drawing supports the continuation of a teaching model despite the transformative influence of digital tools.

Is this second research question, we also discussed certain assertions in the literature, such as the purported direct relationship between creativity and freehand drawing. While freehand drawing possesses attributes fostering creativity, such as the emergence of unexpected ideas, fluent and inspired mental flow, and the involvement of the body in the design process, the data do not allow us to establish this correlation with certainty. In fact, this viewpoint is mainly supported by essayistic literature rather than scientific literature.

Finally, in the search for future perspectives for the use of freehand drawing in design teaching (RQ3), we synthesized proposals from the existing literature with insights derived from evidence-based observations and subsequent analysis. Literature suggestions include reinforcing the connections between freehand drawing and other traditional forms of representation with digital tools in students' design processes, integrating digital drawing into design education, particularly in design critiques, and leveraging digital features to engage students in drawing education.

Moreover, emphasizing the importance of freehand drawing in design teaching, we highlighted the essential need to tailor these proposals to specific contexts. Acknowledging

that the effectiveness observed in one educational setting may not seamlessly apply to another, we propose three distinct perspectives on the role of freehand drawing.

The first perspective, referred to as the consolidation perspective, aims to reinforce the role of freehand drawing in design teaching by instructors. Instructors should articulate the benefits and practical applicability of freehand drawing, explicitly demonstrating how it can be integrated into the design process at specific stages and in conjunction with other forms of representation. It is key to clearly convey the practical utility of this knowledge to students.

The second perspective, referred as the transition perspective, and linked to the first, involves exploring the relationship between conventional and digital freehand drawing. This transition could sustain the qualities associated with conventional freehand drawing and its importance in design education. The digital realm not only offers advantages in enhancing traditional forms of representation, as demonstrated in this research, but also serves as a stimulus for students to develop consistent interest and proficiency.

The third perspective, termed the training perspective, focuses on providing students without drawing knowledge with basic training, such as sketchnotes, to promote its use as a design tool. Despite some students already using it intuitively, this method expands possibilities and strengthens their skills in perspective use and understanding, contributing to improved manual proficiency. In line with Nørgaard's (2017) proposal, the learning of these sketchnotes could be incorporated within the design studio, considering both conventional and digital drawing.

In addition to the general data collected from the three schools, the complementary readings also help clarify specific aspects of each institution. For example, they shed light on how freehand drawing is taught at FAUP and its intersections with the design studios of corresponding years. It was through this finer analysis of how drawing is taught and how this teaching relates to what happens in the design studios that it was understood to be a general curriculum strategy. The teaching of drawing is not limited to drawing courses, but to its counterpart in the design studios of the same year.

Another significant contribution of the complementary readings is documenting the period of online teaching during the Covid-19 pandemic. What started as a constraint caused by the pandemic emergency, conditioning data collection in person, became an opportunity to collect data during the period of online and hybrid teaching, and to compare them with the in-person modality.

This was a key aspect of our research, which demonstrated the decisive importance of freehand drawing, and how the impossibility of using it caused it to migrate to digital support, in a demonstration of adaptability to circumstances, and the possible transfer of

the technique and knowledge associated with hand drawing to digital support. In this regard, it was particularly valuable due to the recording of a substantial amount of visual evidence, including pictures and videos, which can be instrumental in discussing the future of design teaching, and as we have seen, particularly of digital drawing.

Finally, the complementary reading that explored the MIT archive, perhaps the most divergent study from the general methodology of this research, produced truly intriguing results and highlighted relationships that were not known: the relationship between the drawings produced by students since the foundation of the school and systematically stored in the archive, with the curricular plans of the corresponding years, in order to identify how these two have influenced each other.

Whether from the perspective of the methodology used or the empirical evidence gathered and analyzed, this was a crucial aspect of this research, enabling the association of a historical research dimension and its characteristics, such as the ability to identify the reasons behind events (Gunn and Faire 2012). This was a work that emerged during the fieldwork, first as a parallel study, and later integrated into the research.

What we see is that our analysis relied on diverse types of evidence to help support the conclusions of this research. In addition to the symmetric analysis developed on equal terms for the three schools, this set of complementary readings focusing on very specific aspects, sometimes associated with only one of the case studies, but also different types of evidence and research methods, took advantage of the valuable resources found in each case study. However, it is through the intersection of these different sub-studies that emerge from the fieldwork itself, as unexpected discoveries, that the conclusions of this research are grounded.

This, therefore stands as one of the key benefits of conducting a study of this nature. Following Yin's (1994) recommendation, fieldwork starts with a provisional methodological framework, encompassing the procedures to be implemented, the units of analysis, and even the research questions. All of these components were continuously adjusted and refined until reaching a stable state, nearing the conclusion of the study. This approach allowed for the rigorous execution of fieldwork activities while maintaining sufficient openness and flexibility to accommodate adaptations or the incorporation of new aspects that emerged during the research process.

As highlighted in the literature review, one of the research gaps in the field of design education, particularly concerning freehand drawing, is associated with data collection and analysis methods. Many of the associated procedures fail to meet the requirements of validity and reliability. Additionally, a substantial portion of the literature lacks an evidence-based approach or, at the very least, does not systematically address it.

On the other hand, we noticed that the consulted literature used experimental research designs, with only two employing the case study approach, and that data collection methods were primarily experiments and questionnaires. None of the analyzed studies used observation as a research method, which we perceived as a crucial aspect of this type of study for accessing contemporary, contextually situated events. Both in data collection and analysis, the lack of precedent studies to serve as references was a difficulty we had to overcome during the work. The procedures followed can thus serve as a contribution to future studies in similar contexts.

One of the key contributions of this research, as we have repeatedly emphasized throughout the thesis, is then related to its methodological component, whether through the process of defining the main procedures to be followed for data collection and analysis, or through the fieldwork itself, the detailed documentation of which can serve as a transferable resource for future studies. By doing so, we can ensure that research is based on stable methodological assumptions, which, in turn, guarantee its quality and reliability. Simultaneously, this approach allows us to make meaningful contributions to the broader knowledge base in our field.

7.3 Limitations and future work

One of the limitations of this study is related to its timeframe, which, due to technical and logistical constraints, could not be as detailed nor as comprehensive as initially planned. The intention was to consider all design studios from the three institutions, covering all academic years. It became evident as the work progressed that the volume of necessary fieldwork, as well as all subsequent transcription, organization, and finally, analysis work, would be impracticable in a piece of research of this nature.

Therefore, fieldwork was redefined to analyze at least one design studio per academic year in each of the schools, to ensure a broad perspective of the entire curriculum. It is important to note that the results presented in this research pertain specifically to the observations made by the candidate, as referred in the attached table (refer to Appendix 2), and should not be interpreted as generalizable to all cases under study.

This difficulty was compounded, as previously mentioned, by the lack of previous reference studies and the consequent need for methodological definition and a long process of trial and error to stabilize data collection and analysis procedures. Likewise, time issues occurred due to unforeseen hiccups caused by the selection and learning of the necessary software for data storage and organization, and its subsequent analysis.

The importance of this analysis, as evidenced by the procedures followed and the results presented, highlights the potential for conducting it more comprehensively, beyond the

scope of a single researcher's work. Future work could entail a similar configuration analysis, resorting to the methodology already tested, executed by a team across the three schools. Additionally, we envision that this analysis could be applied to other schools, not necessarily centered on the topic of freehand drawing, but applicable to various aspects of design education.

Another limitation stemmed from the candidate's intention to conduct experiments with students while serving as a teaching assistant at Politecnico di Milano. This was envisioned as a complement to the already completed observation sessions. However, it became evident that executing such experiments would be challenging, primarily due to the methodological complexities involved in systematically establishing cause-and-effect relationships, as well as the logistical challenges of balancing research and teaching responsibilities concurrently. It was imperative for the objectives of the design studio to be met effectively. Consequently, the candidate opted to keep following the same procedures for fieldwork, albeit acknowledging that the teaching assistant role provided valuable specific insights, such as student difficulties in representation. This period of teaching assistance is delineated in the attached table (refer to Appendix 2).

A future work of relevance would involve the association of experiments as research methods in focus groups that were representative of the design studios under analysis. One of the experiments to be conducted would be to test design critiques in a hybrid environment, where the possibilities of digital are combined with the use of hand drawing, in this case, digital hand drawing. This approach would enable the testing and evaluation of correlations identified in this research, aligning with Yin's (2011) recommendation to diversify viewpoints.

One critical aspect of this research was the informal conversations held with instructors and students during observation sessions in the design studios, which is a common strategy in qualitative studies (Merriam, 2009). These conversations provided access to information that would be difficult to obtain otherwise. Additionally, they allowed for the testing of research materials, such as intermediate conclusions, analysis categories, and procedures, which yielded valuable feedback. However, a limitation arose during the final phase of the research, where it was not feasible to engage in similar conversations.

A future task would implicate discussing the research findings with the instructors and students involved in this study. The discussion would provide them a comprehensive understanding of the work conducted, gather feedback, and potentially allow them to benefit from the developed insights. Additionally, implementing the final proposals of this research related to the use of freehand drawing, testing them, and evaluating their outcomes would be another task to be undertaken.

Some of the lines of study that were opened in this research could also be further developed, especially the two complementary readings related to online teaching and the drawings of former students of MIT. As complementary analyses, it was not possible in this research to exhaust the results that could be obtained from them. However, both the topic and the evidence collected have great scientific potential and could be further explored in the future.

Regarding the collected data, one of the limitations of this research was the collection of visual evidence during the fieldwork sessions in the design studios. Visual evidence could have significantly enriched the analysis by allowing cross-referencing with written evidence and enhancing the presentation of results. Although a considerable amount of visual data was gathered, it was not done systematically and exhaustively, as originally intended, due to the desire to minimize interference with the subjects under study during observation sessions. In many instances, the candidate refrained from recording photographs and videos in order to minimize disruption to the events being studied.

This difficulty was partly overcome by visits to the rooms where the design studios were held outside of class time, to record in photography and video the representations produced by students and instructors, or to follow the work of some students outside of class time. Interestingly, during the period of online teaching amid the pandemic, this collection of visual evidence was significantly facilitated by the context itself, resulting in the recording of many complete classes. This proved immensely useful in the subsequent analysis and interpretation of data.

A future task would imply a setup of one or more fixed cameras in the classroom, to fully record the class period, following for example the work done by Milovanovic (2019) in monitoring design critiques. However, in order to maintain coherence with the principles followed in this analysis, the use of cameras should minimize interference with educational activities, ensuring that instructors and students are not disrupted during design studios, thus avoiding turning observation into an experimental method. Another way to overcome this difficulty would be to form a team of at least two researchers, so that one could be entirely dedicated to the recording of visual evidence.

Finally, and emphasizing again one of the aspects that we have repeated in this research, the issue of the methodological component. An important future task would be to deepen the systematization of a methodological framework for research in architecture. Despite some existing efforts, as seen in Groat and Wang (2013), there remains substantial work to be done in this area. This would be a crucial aspect for the development of research in architecture, to enhance the its quality, and on the other hand, to gain insights into what distinguishes architectural research. This particularity stems from architectural education's specialized background, encompassing its body of knowledge and skill set.

Moreover, especially in studies based on qualitative methodology, this would involve the recognition of contributions from other disciplines, such as the social sciences, to understand how they can contribute to architectural research. As referred by the AIA Architectural Research Agenda (2018), this is because architectural problems are not exclusively confined to the discipline and, therefore, can hardly be addressed solely from an architectural perspective, requiring the participation or collaboration with other fields of knowledge.

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Appendix 1 Systematic literature review

The table presented here refers to the systematic literature review mentioned in Chapter 1 and Chapter 6.

	general						evidence	approach	design	methods	description	topic					research_questions		
id	authors	title	year	database	doc_type	classification						topic	keywords	most_keywords	importance	shared_ref	rq1	rq2	rq3
1	Putra A.M., Hardiman G., Sardjono A.B., Madyatmadja E.D., Cahyandari G.O.I.	The effect of manual sketching on architectural design process in digital era	2022	Scopus	article	(3) to keep	y	QUAN	experimental	experiment; questionnaire;	clear	(1) considering both sketching and digital means	architectural sketches; drawing; freehand sketching manual drawing; manual sketching; observational drawing;	drawing (72) design (47) students (46) process (42) sketching (27)	important	Goldschmidt G; Gero J; Edwards B;	[part_design process] [tool_communication] [tool_documentation] [tool_observation] [tool_thinking] [tool_visualization] [when_early stages]	[allows_expression] [allows_sensible perception] [allows_unexpected discoveries] [promotes_creativity] [quality_abstraction] [quality_bodily factors] [quality_speed] [relation_drawing skills-design quality] [supports_complex operations] [supports_geometric-spacial understanding] [supports_visual memory] [teaching_propaedeutic]	[improve_design representation_hybrid drawings] [improve_design representation_manual-digital relation] [improve_drawing teaching_students' interest; information technology]
2	Eren E.T., Yılmaz S.	The student attitudes towards digital and conventional drawing methods in environmental design studios and the impact of these techniques on academic achievement in the course	2022	Scopus, Eric	article	(3) to keep	y	MIX	experimental	experiment; questionnaire; interview;	clear	(1) considering both sketching and digital means	conventional drawing; drawings; hand drawings; sketching; visual language;	design (296) drawing (202) techniques (193) digital (151) students (141)	neutral	Goldschmidt G; Gero J; Ferguson G; Schön D;	[part_design process] [tool_observation] [tool_thinking] [tool_visual language] [tool_visualization]	[allows_expression] [promotes_creativity] [relation_drawing skills-design quality] [supports_geometric-spacial understanding] [supports_visual memory] [teaching_propaedeutic]	[improve_design representation_digital drawing] [improve_design teaching_students' interest; digital drawing] [new approach_design teaching_blended design studio]
3	Leandri G.	Architecture and digital drawing tablets, bringing back human control over HAL	2021	Scopus	conference paper	(3) to keep	n	n	n	n	not mentioned	(2) considering digital drawing	drawing; freehand drawing; freehand sketching; representation; traditional drawing;	drawing (53) digital (34) architecture (29) computer (25) hand (24)	important	Lawson B;	[part_teaching process] [tool_observation] [tool_thinking]	[allows_authorship] [allows_expression] [promotes_creativity]	[improve_design representation_digital drawing]
4	Taraszkiewicz A.	Freehand drawing versus digital design tools in architectural teaching	2021	Scopus	article	(4) to keep	y	QUAL	case study	artifact analysis; questionnaire	unclear	(1) considering both sketching and digital means	drawing; freehand drawing; hand drawing; sketch; sketching; visual communication;	design (76) drawing (69) digital (47) students (48) architectural (46)	important		[part_design process] [part_teaching process] [tool_communication] [tool_visualization] [when_desk critiques] [when_early stages] [when_later stages] [when_rarely in the final study]	[promotes_collaboration] [promotes_creativity] [quality_ambiguity] [quality_speed] [quality_transformability] [teaching_complements verbal comm] [teaching_demonstration]	[improve_design representation_digital drawing] [improve_design representation_manual-digital relation]
5	Hsu T.-W., Tsai M.-H., Babu S.V., Hsu P.-H., Chang H.-M., Lin W.-C., Chuang J.-H.	Design and Initial Evaluation of a VR based Immersive and Interactive Architectural Design Discussion System	2020	Scopus, WOS	conference paper	(3) to keep	y	MIX	experimental	experiment; questionnaire;	clear	(3) a new approach to teach design; (2) considering digital drawing	design drawings; drawing; sketching;	design (140) discussion (102) system (74) participants (66) virtual (57)	neutral	Goldschmidt G;	[part_design process] [part_teaching process] [when_early stages]	[teaching_complements verbal comm]	[new approach_design teaching_VR; digital drawing]
6	Juzwa N., Krotowski T.	Sketch-Computer-Imagination Reflections on Architecture Education Methodology	2018	Scopus, WOS	conference paper	(3) to keep	n	n	n	n	not mentioned	(1) considering both sketching and digital means	drawing; freehand sketching; sketch; visualizations;	design (34) architecture (32) idea (22) process (18) architectural (18)	important		[part_design process] [part_teaching process] [tool_thinking] [tool_visualization] [when_early stages]	[promotes_creativity] [quality_abstraction] [quality_ambiguity] [teaching_complements verbal comm]	
7	Akdag, SG	Digital sketching in design education	2018	WOS	conference paper	(4) to keep	y	QUAL	experimental	experiment; questionnaire;	clear	(2) considering digital drawing	drawing; forms and representation; freehand sketching; sketching; visual representation;	digital (60) education (59) sketching (58) design (42) learning (39)	but	Ferguson G;	[part_design process] [tool_observation] [tool_problem-solving] [when_early stages]	[allows_sensible perception] [allows_unexpected discoveries] [promotes_creativity] [promotes_exploration] [quality_ambiguity] [relation_drawing skills-design quality] [supports_complex operations]	[improve_design representation_digital drawing]
8	Nicolau, I; Anghel, AA; Mohora, I	Teamwork strategies and methods to improve drawing skills for students (case study: university of architecture and urbanism, timisoara, interior design department)	2018	WOS	conference paper	(3) to keep	y	QUAL	experimental	experiment;	clear	(4) a new approach to teach sketching	drawing; hand drawing; hand-made sketches; hand sketching; physical drawing; sketching;	drawing (110) student (74) draw (34) team (27) group (26)	important	Edwards B;	[part_design process] [tool_learning] [tool_observation] [tool_problem-solving] [tool_thinking] [tool_visualization]	[allows_sensible perception] [promotes_creativity] [quality_autonomy(PC)] [quality_bodily factors] [relation_drawing skills-design quality] [supports_geometric-spacial understanding] [teaching_different backgrounds] [teaching_propaedeutic]	[improve_drawing teaching_students' interest] [improve_drawing teaching_teamwork]
9	Norgaard, M	Can you picture this? Instructions for using sketchnotes to help novices improve their design sketching skills	2017	WOS	conference paper	(3) to keep	n	n	n	n	not mentioned	(4) a new approach to teach sketching	drawing; sketching; sketchnotes; hand drawn sketches; hand drawing; hand-drawn visualization; handmade drawings;	design (40) students (54) sketching (35) sketchnotes (32) techniques (30)	important	Ferguson G; Schön D;	[part_design process] [tool_annotation] [tool_communication] [tool_documentation] [tool_thinking] [tool_visual language]	[promotes_exploration] [promotes_reflection-in-action] [quality_all-in-one] [supports_visual memory]	[new approach_drawing teaching_sketchnotes]
10	Alipour L., Faizi M.	A new strategy to reduce design fixation: The middle sketching stage	2016	WOS	conference paper	(3) to keep	y	QUAN	experimental	experiment;	clear	(4) a new approach to teach sketching	drawing; representation; sketches; sketching;	design (177) fixation (56) middle stage (47) designers (37) sketching (26)	neutral	Goldschmidt G; Gero J; Lawson B; Cross K;	[part_design process] [tool_thinking] [tool_visualization]	[promotes_creativity] [quality_abstraction] [quality_transformability]	

	general						evidence	approach	design	methods	description	topic					research_questions		
id	authors	title	year	database	doc_type	classification						topic	keywords	most_keywords	importance	shared_ref	rq1	rq2	rq3
11	Špaček R., Peciar M., Šíp L.	Sketching and drawing in the new age - the role of sketching and drawing in architectural and technical education	2016	WOS	article	(3) to keep	n	n	n	n	not mentioned	(1) considering both sketching and digital means	drawing; sketching;	design (30) drawing (29) work (27) digital (24) sketching (22)	important		[part_design process] [tool_thinking] [tool_visualization]	[promotes_creativity] [promotes_exploration] [quality_bodily factors] [quality_transformability]	[improve_design representation_manual-digital relation]
12	Yossef M.N.A., Salama H.A.F.	The power of manual sketching in design	2013	Scopus	article	(3) to keep	n	n	n	n	not mentioned	(1) considering both sketching and digital means	drawing; freehand drawing; manual sketch; manual sketching; sketching;	sketch (83) design (77) sketching (56) sketches (53) concept (40)	important		[part_design process] [tool_communication] [tool_documentation] [tool_thinking] [when_early stages]	[allows_expression] [promotes_collaboration] [promotes_creativity] [promotes_exploration] [quality_abstraction] [teaching_demonstration] [teaching_documents the process]	[improve_design representation_digital drawing]
13	Nováková K., Achten H., Matějovská D.	Towards Improved Architecture Education A Research Framework	2011	Scopus	conference paper	(4) to keep	y	MIX	case study	direct observation; questionnaire; experiment;	unclear	(1) considering both sketching and digital means	drawing; sketching	design (52) students (36) process (15) research (13) cad (14)	but	Goldschmidt G; Lawson B; Cross K;	[part_design process] [part_teaching process] [tool_annotation] [tool_communication] [tool_documentation] [tool_observation] [tool_problem-solving] [tool_thinking]	[allows_expression] [promotes_creativity] [promotes_reflexion-in-practice] [quality_abstraction] [quality_easiness] [quality_speed] [quality_transformability] [supports_visual memory]	[improve_design representation_digital drawing] [improve_design representation_manual-digital relation] [improve_design teaching_drawing as interactive tool]
14	Soygenis S., Soygenis M., Erktin E.	Writing as a Tool in Teaching Sketching: Implications for Architectural Design Education	2010	Scopus, WOS, Eric	article	(3) to keep	y	QUAN	experimental	experiment; report analysis;	clear	(4) a new approach to teach sketching	drawing; prescriptive sketch; representational drawing; sketches; sketching; talking sketch; thinking sketch;	sketching (73) thinking (69) students (67) sketch (63) visual (55)	important	Goldschmidt G; Gero J; Ferguson G;	[part_design process] [part_teaching process] [tool_annotation] [tool_communication] [tool_thinking] [tool_visualization] [when_early stages]	[allows_expression] [allows_unexpected discoveries] [promotes_creativity] [promotes_reflexion-in-practice] [quality_easiness] [quality_speed] [teaching_complements verbal comm]	[improve_design representation_manual-digital relation] [new approach_drawing teaching_reflexive pedagogy] [new approach_drawing teaching_writing]
15	Domínguez E.R., Roma G.S.	Teaching methodologies based on touch interfaces for the teaching of drawing and architectural projects [Metodologías docentes basadas en interfases táctiles para la docencia del dibujo y los proyectos arquitectónicos]	2010	Scopus	article	(3) to keep	y	MIX	experimental	experiment; questionnaire;	clear	(4) a new approach to teach sketching; (2) considering digital drawing	drawing; freehand drawing; sketch; sketching;	dibujo (75) docencia (36) proyetos (35) arquitectónico (34) digital (33)	but	Gross MD;	[part_design process] [part_teaching process] [tool_communication] [tool_thinking] [tool_visualization]		[improve_design representation_hybrid drawings] [improve_design representation_manual-digital relation] [new approach_drawing teaching_digital drawing]
16	Akalin A., Sezal I.	The Importance of Conceptual and Concrete Modelling in Architectural Design Education	2009	Scopus, W	article	(3) to keep	y	QUAL	experimental	experiment;	unclear	(4) a new approach to teach sketching	drawing; sketches; sketching;	design (89) modelling (40) students (52) phase (34) studio (33)	neutral	Edwards B;	[part_design process] [part_graphic diaries] [part_teaching process] [tool_analysis] [tool_annotation] [tool_communication] [tool_observation] [tool_problem-solving] [tool_thinking] [tool_visualization]	[allows_expression] [quality_bodily factors] [supports_complex operations] [supports_visual memory]	
17	Dokonal W., Knight M.	Pen or PC?: Is Sketching essential to architectural design?	2006	Scopus	conference paper	(3) to keep	n	n	n	n	not mentioned	(1) considering both sketching and digital means	drawing; manually sketch; sketching;	design (89) digital (44) students (44) analogue (31) group (27)	neutral	Gross MD;	[part_design process] [tool_thinking] [tool_visualization] [when_early stages]		[improve_design representation_manual-digital relation]
18	Olmos, F	A training model to develop design skills in the virtual design studio	2006	WOS	conference paper	(3) to keep	y	MIX	experimental	experiment; questionnaire; interview; artifact analysis; direct observation;	clear	(3) a new approach to teach design; (2) considering digital drawing	drawing; sketches; sketching;	design (99) learning (47) course (39) training (69) virtual (50)	neutral	Lawson B; Schön D;	[part_teaching process] [tool_learning] [tool_thinking]		[improve_design teaching_students' interest; digital drawing] [improve_design teaching_VR]
19	Senyapili, Burcu;Basa, Yncy	The Shifting Tides of Academe: Oscillation between Hand and Computer in Architectural Education	2006	WOS	conference paper	(3) to keep	y	MIX	experimental	experiment; questionnaire;	unclear	(1) considering both sketching and digital means	drawing; drawing medium; hand drawing; hand drawn; sketching;	design (68) computer (63) hand (62) students (55) education (34)	important	Gero J; Cross K;	[part_design process] [part_teaching process] [tool_visualization]	[allows_authorship] [allows_expression] [allows_sensible perception] [promotes_creativity] [quality_abstraction]	
20	Bailey R.	The student, the master and the computer	2003	Scopus	conference paper	(3) to keep	n	n	n	n	not mentioned	(2) considering digital drawing	drawing; digital sketching;	design (48) student (33)	but	Gross MD;	[part_design process] [part_teaching process]	[allows_expression] [promotes_reflection-in-action]	[improve_design teaching_drawing as interactive tool]

Appendix 2 Three schools of architecture

The table presented here refers to the data collected and analyzed in Chapter 4 and Chapter 6.

id			observer			ua_context																
						class							setting									
id	date	year	monitoring	obs_type	obs_role	class_institution	class_doc_type	class_participant	class_course	class_system	class_type	class_regime	inst_name	inst_num	assistants_num	guests_num	guests_role	brief	brief_program	brief_detailed	brief_nature	brief_context
1	04/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Computation Design Lab	semester	theo, critiques	in-person	Takehiko Hagakura	1	1	3	lecturer	y	practical-design research	n	both	n
2	06/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Creative Computation	semester	mid-term	in-person	Axel Kilian	1	n	n		y	a robotic prototype	n	sy	n
3	06/mai	2022	in-person	non-participant	observer	MIT	OBS	class	Design Option Studio	semester	final	in-person	Angelo Bucci	2	1	3	reviewer	y	equipment (fragile territory)	n	both	real
4	07/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Core Studio 2	semester	critiques	in-person	Cristina Parreno Alonso	1	1	n		y	equipment (historical building)	n	both	real and visitable
5	07/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Design Option Studio	semester	critiques	in-person	Angelo Bucci	2	n	n		y	equipment (fragile territory)	n	both	real
6	08/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Core Studio 2	semester	theo, critiques	in-person	Cristina Parreno Alonso	1	1	1	lecturer	y	equipment (historical building)	n	both	real and visitable
7	08/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Design Option Studio	semester	critiques	in-person	Angelo Bucci	2	n	n		y	equipment (fragile territory)	n	both	real
8	09/mai	2022	in-person	non-participant	observer	MIT	OBS	class	Core Studio 2	semester	final	in-person	Cristina Parreno Alonso	1	1	3	reviewer	y	equipment (historical building)	n	both	real and visitable
9	11/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Computation Design Lab	semester	critiques	in-person	Takehiko Hagakura	2	1	n		y	practical-design research	n	both	n
10	11/abr	2022	in-person	non-participant	observer	MIT	OBS	class	How to design	semester	critiques	in-person	Paul Pettigrew	1	2	n		y	lamp, furniture	n	sy	n
11	13/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Creative Computation	semester	theo, critiques	in-person	Axel Kilian	1	n	n		y	a robotic prototype	n	sy	n
12	15/mar	2022	in-person	participant	reviewer	MIT	OBS	class	Design studio 2	semester	mid-term	in-person	Mohamad Nahleh	1	1	3	reviewer	y	free (thematic)	n	both	real and near
13	16/mar	2022	in-person	non-participant	observer	MIT	OBS	class	Furniture workshop	semester	critiques	in-person	Christopher Dewart	1	1	3	reviewer	y	an object (sculpture or furniture)	n	sy	n
14	16/mar	2022	in-person	non-participant	observer	MIT	OBS	class	How to design	semester	mid-term	in-person	Paul Pettigrew	1	2	n		y	lamp, furniture	n	sy	n
15	16/mai	2022	in-person	non-participant	observer	MIT	OBS	class	Design Studio 2	semester	final	in-person	Mohamad Nahleh	1	1	4	reviewer	y	free (thematic)	n	both	real and near
16	25/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Art Studio	semester	critiques	in-person	Renée Green	1	1			y	an exposition	n	sy	real and near
17	28/mar	2022	in-person	non-participant	observer	MIT	OBS	class	Design studio	semester	critiques	in-person	Jeremy Jih	1	2	n		y	series of design object	n	sy	n
18	28/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Core Studio 2	semester	theo, critiques	in-person	Cristina Parreno Alonso	1	1	1	lecturer	y	equipment (historical building)	n	both	real and visitable
19	30/mar	2022	in-person	non-participant	observer	MIT	OBS	class	Design studio	semester	mid-term	in-person	Jeremy Jih	1	2	3	lecturer, reviewer	y	series of design object	n	sy	n
20	31/mar	2022	in-person	non-participant	observer	MIT	OBS	class	BIM	semester	critiques	in-person	Takehiko Hagakura	1	2	n		y	analysing and modulate Alvar Aalto	n	an	n

id			observer			class							ua_context									
													setting									
id	date	year	monitoring	obs_type	obs_role	class_institution	class_doc_type	class_participant	class_course	class_system	class_type	class_regime	inst_name	inst_num	assistants_num	guests_num	guests_role	brief	brief_program	brief_detailed	brief_nature	brief_context
21	03/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 1	annual	critiques	in-person	Giorgio Frassine	2	1	n		y	interior space, school of arts	n	sy	no context
22	03/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 2	annual	critiques	in-person	Martina Landsberger	1	1	n		y	n	n	an	real
23	03/dez	2021				POLIMI	CON	student														
24	04/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 3	semester	critiques	in-person	Barbara Bogoni	1	3	n		y	residency for students	n	both	real and visitable
25	04/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 3	semester	mid-term	in-person	Filippo Bricolo	1	1	1	reviewer	y	urban project, equipment		both	real and near
26	04/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	PHCS	semester	critiques	in-person	Chiara Lanzoni, Carlo Peraboni	2	3	n		y	urban plan	n	both	real and near
27	05/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	ADS	semester	critiques	in-person	Luigi Spinelli, Federico Bucci	2	5	n		y	n	n	an	real and visitable
28	05/dez	2019	in-person	non-participant	observer	POLIMI	OBS	class	ADS	semester	critiques	in-person	Matteo Moscatelli, Chiara Baglione	2	3	n		y	n	n	an	real and visitable
29	08/nov	2021	in-person	participant	assistant	POLIMI	OBS	class	LPA 3	semester	critiques	hybrid	Barbara Bogini, Paulo David	2	1	1	reviewer	y	house with studio (historical building)	n	both	real
30	09/jan	2020	in-person	participant	reviewer	POLIMI	OBS	class	ADS	semester	final	in-person	Luigi Spinelli, Matteo Moscatelli	4	8	3	reviewer	y	n	n	an	real and visitable
31	09/dez	2020	remote	non-participant	observer	POLIMI	OBS	class	LPA 3	semester	final	remote	Barbara Bogoni	1	1	1	reviewer	y	architectural element, residency for students	n	both	real and visitable
32	12/mai	2021	in-person	participant	assistant	POLIMI	OBS	class	ADHCS	semester	critiques	hybrid	Barbara Bogoni, Luigi Spinelli	2	2	3	reviewer	y	pavilion (historical context)	n	both	real and near
33	20/out	2021	in-person	participant	assistant	POLIMI	OBS	class	LPA 3	semester	critiques	hybrid	Barbara Bogoni, Paulo David	2	1	1	reviewer	y	house with studio (historical building)	n	both	real
34	03/nov	2021	in-person	participant	assistant	POLIMI	OBS	class	LPA3	semester	critiques	Hybrid	Barbara Bogoni	1	1	n		y	house with studio (historical building)	n	both	real
35	22/jan	2020	in-person	non-participant	observer	POLIMI	OBS	class	LPA 3	semester	final	in-person	Filippo Bricolo	2	1	3	reviewer	y	urban project, equipment	n	both	real and near
36	23/fev	2021				POLIMI	CON	prof					Barbara Bogoni, Luigi Spinelli									
37	24/fev	2021	remote	non-participant	observer	POLIMI	OBS	class	ADHCS	semester	theo	hybrid	Barbara Bogoni, Luigi Spinelli	2	2	2	lecturer				both	real and near
38	24/jun	2021	in-person	participant	assistant	POLIMI	OBS	class	ADHCS	semester	final	hybrid	Barbara Bogoni, Luigi Spinelli	2	2	1	reviewer	y	pavilion (historical context)	n	both	real and near
39	25/fev	2021	remote	non-participant	observer	POLIMI	OBS	class	ADHCS	semester	theo, exercise	hybrid	Barbara Bogoni, Luigi Spinelli	2	2	1	lecturer	y	pavilion	n	both	real and near
40	25/nov	2019	in-person	non-participant	both	POLIMI	OBS	class, student	LPA 3	semester	mid-term, critiques	in-person	Barbara Bogoni, Paulo David	2	3	1	reviewer	y	architectural element, residency for students	n	both	real and visitable
41	26/mai	2021	in-person	participant	assistant	POLIMI	OBS	class	ADHCS	semester	critiques	hybrid	Barbara Bogoni, Luigi Spinelli	2	2	1	reviewer	y	pavilion (historical context)	n	both	real and near

id			observer			class							ua_context									
													setting									
id	date	year	monitoring	obs_type	obs_role	class_institution	class_doc_type	class_participant	class_course	class_system	class_type	class_regime	inst_name	inst_num	assistants_num	guests_num	guests_role	brief	brief_program	brief_detailed	brief_nature	brief_context
42	26/nov	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 1	annual	critiques	in-person	Massimo Ferrari, Claudia Tinazzi	2	n	n		y	classroom, small school	n	sy	no context, real
43	27/nov	2019	in-person	non-participant	observer	POLIMI	OBS	class	LPA 3	semester	critiques	in-person	Filippo Bricolo	1	1	n		y	urban project, equipment	n	both	real and near
44	28/nov	2019	in-person	non-participant	observer	POLIMI	OBS	class	ADS	semester	critiques	in-person	Luigi Spinelli	1	3	n		y	n	n	an	real and visitable
45	30/jan	2020	in-person	non-participant	observer	POLIMI	OBS	class	ADS	semester	final	in-person	Luigi Spinelli	1	3	n		y	n	n	an	real and visitable
46	01/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	theo	remote	Helder Casal Ribeiro	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
47	01/mar	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 2	annual	critiques	remote	Madalena Pinto Silva	1	n	n		y	residency for students	y	sy	real and near
48	02/mar	2021				FAUP	CON	student														
49	02/mar	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 4	annual	critiques	remote	Adalberto Dias	1	n	n		y	equipment (historical building), equipment (new building)	y	sy	real and visitable
50	02/mar	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 4	annual	critiques	remote	Nuno Brandão Costa	1	n	n		y	equipment (historical building), equipment (new building)	y	sy	real and visitable
51	03/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	remote	Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
52	04/jan	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	theo, exercise	remote	Helder Casal Ribeiro	1	n	1	lecturer	y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
53	04/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	remote	Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
54	06/jan	2021	in-person	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	visit, critiques	in-person	Helder Casal Ribeiro, Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
55	07/jan	2021	in-person	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	in-person	Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
56	10/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 3	annual	critiques	remote	Rui Ramos	1	n	n		y	urban project, multi-housing building	y	sy	real and visitable
57	11/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 3	annual	critiques	remote	Luis Soares Carneiro	1	n	n		y	urban project, multi-housing building	y	sy	real and visitable
58	12/jan	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 5	annual	mid-term	remote	Teresa Calix	3	n	n		y	Urban plan	y	both	real and visitable
59	13/jan	2021	in-person	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	in-person	Helder Casal Ribeiro	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
60	13/jan	2021	in-person	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	in-person	Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near

id			observer			class							ua_context									
													setting									
id	date	year	monitoring	obs_type	obs_role	class_institution	class_doc_type	class_participant	class_course	class_system	class_type	class_regime	inst_name	inst_num	assistants_num	guests_num	guests_role	brief	brief_program	brief_detailed	brief_nature	brief_context
61	14/jan	2021	in-person	non-participant	observer	FAUP	OBS	class	Projeto 1	annual	critiques	in-person	Rui Cardoso	1	n	n		y	two exposition rooms and a foyer (for given objects)	y	sy	real and near
62	15/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 3	annual	critiques	remote	Luis Soares Carneiro	1	n	n		y	urban project, multi-housing building	y	sy	real and visitable
63	15/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 3	annual	critiques	remote	Rui Ramos	1	n	n		y	urban project, multi-housing building	y	sy	real and visitable
64	22/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 2	annual	critiques	remote	Madalena Pinto Silva	1	n	n		y	residency for students	y	sy	real and near
65	23/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 4	annual	critiques	remote	Adalberto Dias	1	n	n		y	equipment (historical building), equipment (new building)	y	sy	real and visitable
66	25/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 4	annual	critiques	remote	Nuno Brandão Costa	1	n	n		y	equipment (historical building), equipment (new building)	y	sy	real and visitable
67	25/fev	2021	remote	non-participant	observer	FAUP	OBS	class	Projeto 4	annual	critiques	remote	Adalberto Dias	1	n	n		y	equipment (historical building), equipment (new building)	y	sy	real and visitable
68	25/nov	2020	in-person	non-participant	observer	FAUP	OBS	class	Projeto 2	annual	critiques	in-person	Madalena Pinto Silva	1	n	n		y	residency for students	y	sy	real and near
69	07/jul	2019				FAUP	CON	former prof					Manuel Nicolau Brandão									
70	14/out	2021				FAUP	CON	former prof														
71	17/nov	2020				FAUP	CON	prof														
72	05/abr	2022				MIT	CON	prof					Mark Jarzombek									
73	06/abr	2022				MIT	CON	prof					Mark Jarzombek									
74	07/mar	2021				MIT	CON	prof					Mark Jarzombek									
75	13/jun	2022				MIT	CON	prof					Mark Jarzombek									
76	29/mai	2022				POLIMI	CON	student														
77	06/dez	2019				POLIMI	CON	prof					Federico Bucci									
78	07/mai	2021	in-person	participant	assistant	POLIMI	OBS	class	ADHCS	semester	critiques	hybrid	Barbara Bogoni, Luigi Spinelli	1	2	n		y	pavilion (historical context)	n	both	real and near
79	21/mai	2021	in-person	participant	assistant	POLIMI	OBS	class	ADHCS	semester	critiques	hybrid	Barbara Bogoni, Luigi Spinelli	1	2	n		y	pavilion (historical context)	n	both	real and near
80	02/jul	2021				FAUP	CON	student														
81	11/abr	2022	in-person	non-participant	observer	MIT	OBS	class	Design studio	semester	final	in-person	Jeremy Jih	1	2	3	lecturer, reviewer	y	series of design object	n	sy	n

	brief							models						representation					ua_design_process	
id	brief_modality	brief_group	brief_plan	brief_restrictions	brief_deliver	brief_class_w	mdl	mdl_production	mdl_materials	mdl_style	mdl_character	mdl_scales	rep	rep_balance	rep_types	rep_most_types	rep_support	rep_character	rep_style
1	individual		n	n	dossier	n							digital	entirely digital	technical, scheme, photo, video/animation	scheme	digital	static	stylized
2	individual		n	n	dossier, prototype	p		handmade	styrofoam, acrylic, metal, fabric	prototype	static	1.1	both	mostly digital	technical, scheme, photo, video/animation, fhd, render	scheme	plain paper, notebook, digital	both	technical
3	individual		n	n	plans, dossier, models	y		both	cardboard, wood, metal, styrofoam, prototype	abstract, thematic, realistic	static	1.500, 1.100, 1.50	both	balanced	techincal, scheme, render, perspective, fhd	technical	plain paper, tracing paper, digital, notebook	both	stylized, technical
4	group	2	n	n	plans, model, dossier	y		handmade	styrofoam, acrylic, metal, cardboard	abstract, thematic	static	1.500, 1.100, 1.50	both	mostly digital	technical, scheme, render, perspective, fhd	technical	plain paper, notebook, tracing paper, digital	both	stylized, technical
5	individual		n	n	plans, dossier, models	y		both	cardboard, wood, metal, styrofoam, prototype	abstract, thematic, realistic	static	1.500, 1.100, 1.50	both	balanced	techincal, scheme, render, perspective, fhd	technical	plain paper, tracing paper, digital, notebook	both	stylized, technical
6	group	2	n	n	plans, model, dossier	y		handmade	styrofoam, acrylic, metal, cardboard	abstract, thematic	static	1.500, 1.100, 1.50	both	mostly digital	technical, scheme, render, perspective, fhd	technical	plain paper, notebook, tracing paper, digital	both	stylized, technical
7	individual		n	n	plans, dossier, models	y		both	cardboard, wood, metal, styrofoam, prototype	abstract, thematic, realistic	static	1.500, 1.100, 1.50	both	balanced	techincal, scheme, render, perspective, fhd	technical	plain paper, tracing paper, digital, notebook	both	stylized, technical
8	group	2	n	n	plans, model, dossier	y		handmade	styrofoam, acrylic, metal, cardboard	abstract, thematic	static	1.500, 1.100, 1.50	both	mostly digital	technical, scheme, render, perspective, fhd	technical	plain paper, notebook, tracing paper, digital	both	stylized, technical
9	individual		n	n	dossier	n							digital	entirely digital	technical, scheme, photo, video/animation	scheme	digital	static	stylized
10	individual		n	n	panels, prototype, dossier	p		handmade	paper, cardboard, acrylic, metal	prototype	static	1.1, 1.2	both	mostly digital	technical, render, scheme, perspective, photo, fhd	photo (prototype)	plain paper, digital, notebook	both	stylized
11	individual		n	n	dossier, prototype	p		handmade	styrofoam, acrylic, metal, fabric	prototype	static	1.1	both	mostly digital	technical, scheme, photo, video/animation, fhd, render	scheme	plain paper, notebook, digital	both	technical
12	individual		n	n	panels, models, dossier	y		handmade	cardboard, styrofoam	abstract, thematic	static	1.200, 1.100, 1.50	both	balanced	technical, photo, video, scheme, perspective, fhd	scheme	plain paper, digital, notebook	static	stylized
13	individual		n	n	dossier, prototype	p		handmade	wood				both	balanced	technical, render, scheme, perspective, fhd	technical	plain paper, digital, notebook	both	technical
14	individual		n	n	panels, prototype, dossier	p		handmade	paper, cardboard, metal, acrylic	prototype	static	1.1, 1.2	both	mostly digital	technical, render, scheme, perspective, photo, fhd	photo (prototype)	plain paper, digital, notebook	both	stylized
15	individual		n	n	panels, models, dossier	y		handmade	cardboard, styrofoam	abstract, thematic	static	1.200, 1.100, 1.50	both	balanced	technical, photo, video, scheme, perspective, fhd	scheme	plain paper, digital, notebook	static	stylized
16	individual		n	n	dossier, the exposition	n													
17	group	2	n	n	panels, prototype, dossier	p		handmade	rope, wax, acritic, metal, concrete, plaster	prototype	static	1.1, 1.2	both	mostly digital	technical, render, scheme, photo, fhd	scheme	plain paper, digital, notebook	both	technical, hybrid, stylized
18	group	2	n	n	plans, model, dossier	y		handmade	styrofoam, acrylic, metal, cardboard	abstract, thematic	static	1.500, 1.100, 1.50	both	mostly digital	technical, scheme, render, perspective, fhd	technical	plain paper, notebook, tracing paper, digital	both	stylized, technical
19	group	2	n	n	panels, prototype, dossier	p		handmade	rope, wax, acrylic, metal, concrete, plaster	prototype	static	1.1, 1.2	both	mostly digital	technical, render, scheme, photo, fhd	scheme	plain paper, digital, notebook	both	technical, hybrid, stylized
20	individual		n	n	panels, dossier	n							digital	entirely digital	technical, render, scheme, perspective, video/animation	technical	digital	static	technical

	brief						models						representation						ua_design_process	
id	brief_modality	brief_group	brief_plan	brief_restrictions	brief_deliver	brief_class_w	mdl	mdl_production	mdl_materials	mdl_style	mdl_character	mdl_scales	rep	rep_balance	rep_types	rep_most_types	rep_support	rep_character	rep_style
21	group	4	n	y	panels, models	y		handmade	cardboard	abstract	dynamic	1.50, 1.20	analogue	entirely analogue	technical, perspective, fhd	model is the most used form of representation	plain paper	dynamic	stylized
22	group	3	n	n	dossier, model	y		handmade	cardboard, styrofoam	abstract	static	1.1000, 1.100, 1.50	both	balanced	technical, photo, scheme, perspective, fhd	technical, hard perspectives (made out of technical)	plain paper, digital	static	stylized
23																			
24	group	3	n	n	panels, models	y		handmade	cardboard	abstract	dynamic	1.100, 1.50	both	mostly analogue	technical, perspective	technical by hand, volumetric models	plain paper, tracing paper, notebook	dynamic	stylized, technical
25	group	3	n	n	panels, models	y		handmade	cardboard	abstract, thematic	static	1.500, 1.200, 1.100	both	mostly digital	technical, scheme, collage, render, perspective, fhd		plain paper, cardboard, tracing paper, digital	static	stylized
26	group	4	y	n	dossier, plans	n							both	balanced	technical, scheme, fhd	maps, scheme	plain paper, tracing paper	both	n
27	group	5	y	n	dossier, models	y		both	cardborad, acrylic, wood	abstract, thematic	static	1.100, 1.50, 1.20, 1.10	both	mostly digital	technical, scheme, collage, render, photo perspective, fhd	toy-model, digital axonometry is the most used, only two groups with fhd	plain paper, digital	static	stylized, hybrid, technical
28	group	5	y	n	dossier, models	y		handmade	cardboard	abstract, thematic, realistic	static	1.100, 1.50, 1.20, 1.10	both	mostly digital	technical, scheme, collage, render, photo, perspective, fhd	toy-model, digital axonometry is the most used	plain paper, digital	static	stylized, hybrid, technical
29	group	4	n	n	panels, models	y		handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	plain paper, tracing paper, notebook, digital	both	technical, hybrid, stylized
30	group	5	y	n	dossier, models	y		both	cardboard, wood	abstract, thematic, realistic	static	1.100, 1.50, 1.20, 1.10	both	mostly digital	technical, scheme, collage, render, photo, video, VR, perspective, fhd	toy-model, digital axonometru is the most used	plain paper, cardboard, digital	static	sylized, hybrid, technical
31	individual, group	3	n	n	dossier, models	n							digital	entirely digital	technical, scheme, photo, render	technical	digital	static	technical
32	group	4	y	n	panels, models, dossier	y		handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	digital	both	technical, hybrid, stylized
33	group	4	n	n	panels, models	y		handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	plain paper, tracing paper, notebook	both	technical, hybrid, stylized
34	group	4	n	n	panels, models	y		handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	plain paper, tracing paper, notebook, digital	static	technical, hybrid, stylized
35	group	3	n	n	panels, models	y		handmade	cardboard	abstract, thematic	static	1.500, 1.200, 1.100	both	mostly digital	technical, scheme, collage, render, perspective, fhd	models (very large), images of the design	plain paper, cardboard, tracing paper, digital	static	stylized, thematic
36																			
37						n													
38	group	4	y	n	panels, models, dossier	y		handmade	cardborad	abstract	static	1.200, 1.100, 1.50	both	mostly digital	technical, photo, render, perspective, fhd	technical	digital	static	technical, hybrid, stylized
39	group	4	y	n	panels, model, dossiers	n													
40	individual, group	3	n	n	dossier, models	y		both	cardboard, acrylic	thematic	static	1.20, 1.10, 1.5, 1.1	digital	entirely digital	technical, photo, 3d model, 3d render	models	digital	static	stylized, hybrid
41	group	4	y	n	panels, models, dossier	y		handmade	cardboard	abstract	static	1.200, 1.100, 1.50	both	mostly digital	technical, photo, render, perspective, fhd	technical	digital	static	technical, hybrid, stylized

	brief						models							representation						ua_design_process
id	brief_modality	brief_group	brief_plan	brief_restrictions	brief_deliver	brief_class_w	mdl	mdl_production	mdl_materials	mdl_style	mdl_character	mdl_scales	rep	rep_balance	rep_types	rep_most_types	rep_support	rep_character	rep_style	
42	group	3	n	n	panels, models		y	handmade	cardboard, styrofoam	abstract, realistic	static	1.50, 1.20	both	balanced	technical, render, perspective, fhd	hand drawing and fhd with low quality	plain paper	both	stylized	
43	group	3	n	n	panels, models	large format territorial drawing	y	handmade	cardboard	abstract, thematic	static	1.500, 1.200, 1.100	both	mostly digital	technical, collage, scheme, render,perspective, fhd	few perspective (both digital and handmade), only a group with fhd, toy-model	plain paper, digital	static	stylized	
44	group	5	y	n	dossier, models		y	both	cardborad, acrylic, wood	abstract, thematic	static	1.100, 1.50, 1.20, 1.10	both	mostly digital	technical, scheme, collage, render, photo perspective, fhd	toy-model, digital axonometry is the most used, only two groups with fhd	plain paper, digital	static	stylized, hybrid, technical	
45	group	5	y	n	dossier, models		y	both	cardboard, wood	abstract, thematic, realistic	static	1.100, 1.50, 1.20, 1.10	both	mostly digital	technical, scheme, collage, render, photo, perspective, fhd	toy-model, digital axonometru is the most used	plain paper, cardboard, digital	static	stylized, hybrid, technical	
46	individual		y	y	panels, models		n													
47	individual		y	y	panles, model	a model of the context	y	handmade	cardboard, styrofoam	abstract	static	1.500, 1.200	analogue	entirely analogue	technical, perspective, fhd	technical, fhd	plain paper, tracing paper, notebook	dynamic	technical	
48																				
49	individual		y	n	panles, model		y	handmade	cardboard, styrofoam	abstract	static	1.200, 1.100	digital		technical, perspective, fhd	technical	digital	static	technical	
50	individual		y	n	panles, model		y	handmade	cardboard, styrofoam	abstract	static	1.200, 1.100	digital		technical, perspective, fhd	technical	digital	static	technical	
51	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
52	individual		y	y	panels, models		n													
53	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
54	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
55	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
56	individual		y	n	panels, models		y	handmade	styrofoam, cardboard	abstract	both	1.1000, 1.500	both	balanced	fhd, technical, render	technical	notebook, plain paper, tracing paper, digital	both	technical, hybrid	
57	individual		y	n	panels, models		y	handmade	styrofoam, cardboard	abstract	both	1.1000, 1.500	both	balanced	fhd, technical, render	technical	notebook, plain paper, tracing paper, digital	both	technical, hybrid	
58	group	5	y	n	dossier, panels		n						both	mostly digital	technical, scheme	technical (maps)	digital	static	techincal, hybrid, stylized	
59	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
60	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	

																			ua_design_process	
	brief						models						representation							
id	brief_modality	brief_group	brief_plan	brief_restrictions	brief_deliver	brief_class_w	mdl	mdl_production	mdl_materials	mdl_style	mdl_character	mdl_scales	rep	rep_balance	rep_types	rep_most_types	rep_support	rep_character	rep_style	
61	individual		y	y	panels, models		y	handmade	styrofoam	abstract	dynamic	1.200, 1.50	analogue	entirely analogue	fhd	fhd	notebook, plain paper, tracing paper	dynamic	technical	
62	individual		y	n	panels, models		y	handmade	styrofoam, cardboard	abstract	both	1.1000, 1.500	both	balanced	fhd, technical, render	technical	notebook, plain paper, tracing paper, digital	both	technical, hybrid	
63	individual		y	n	panels, models		y	handmade	styrofoam, cardboard	abstract	both	1.1000, 1.500	both	balanced	fhd, technical, render	technical	notebook, plain paper, tracing paper, digital	both	technical, hybrid	
64	individual		y	y	panels, models	a model of the context	y	handmade	cardboard, styrofoam	abstract	dynamic	1.500, 1.200	analogue	entirely analogue	technical, perspective, fhd	technical, fhd	plain paper, tracing paper, notebook	dynamic	technical	
65	individual		y	n	panles, model		y	handmade	cardboard, styrofoam	abstract	static	1.200, 1.100	digital		technical, perspective, fhd	technical	digital	static	technical	
66	individual		y	n	panles, model		y	handmade	cardboard, styrofoam	abstract	static	1.200, 1.100	digital		technical, perspective, fhd	technical	digital	static	technical	
67	individual		y	n	panles, model		y	handmade	cardboard, styrofoam	abstract	static	1.200, 1.100	digital		technical, perspective, fhd	technical	digital	static	technical	
68	individual		y	y	panels, models	a model of the context	y	handmade	cardboard, styrofoam	abstract	dynamic	1.500	analogue	entirely analogue	technical, perspective, fhd	technical, fhd	plain paper, tracing paper, notebook	dynamic	technical	
69																				
70																				
71																				
72																				
73																				
74																				
75																				
76																				
77																				
78	group	4	y	n	panels, models, dossier		y	handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	plain paper, tracing paper, notebook, digital	both	technical, hybrid, stylized	
79	group	4	y	n	panels, models, dossier		y	handmade	cardboard	abstract	static	1.200, 1.100	both	mostly digital	technical, photo, render, perspective, fhd	technical	plain paper, tracing paper, notebook, digital	both	technical, hybrid, stylized	
80																				
81	group	2	n	n	panels, prototype, dossier		p	handmade	rope, wax, acrylic, metal, concrete, plaster	prototype	static	1.1, 1.2	both	mostly digital	technical, render, scheme, photo, fhd	scheme	plain paper, digital, notebook	both	technical, hybrid, stylized	

			freehand_drawing						difficulties		critiques					
id	rep_scales	rep_construction	fhd	fhd_demanded	fhd_presence	fhd_what	fhd_how	fhd_where	diff_general	diff_representation	cri_setting	cri_class_review	cri_dynamics	cri_comentaries	cri_suggestions	cri_actions
1	1.5000, 1.1000, 1.500, 1.200, 1.100	n	n								individual	y	projected			n
2	1,1	y	y	spontaneously	medium	design	technical, scheme	plain paper, notebook, digital			individual	y	projected	on_construction, on_design, on_presentation, on_process	improve_design, alternative_design, improve_representation, improve_presentation	hybrid_interaction, inter_software, model_manipulation
3	1.200, 1.100, 1.50	y	y	spontaneously	medium	design	technical, scheme, perspective, note	plain paper, notebook, digital		tech_representation, static_representation	individual	n	instructor moves	on_construction, on_presentation, on_representation, references_architecture, references_general, purposes_teaching, on_design, on_process, on_social		n
4	1.200, 1.100, 1.50	y	y	spontaneously	medium	design, communication	technical, scheme, perspective	plain paper, notebook, digital		deal_scale, lag_abstract-reality, static_representation	group	n	students move	on_presentation, on_representation, principles_representation, principles_desinging, on_process, references_architecture	improve_design, improve_presentation, alternative_process, alternative_design, dynamic_representation, see_reference	speech_drawing
5	1.200, 1.100, 1.50	y	y	spontaneously	medium	design	technical, scheme, perspective	plain paper, notebook, digital	lag_analysis-design, instructor_approval	deal_scale, lack_perspective, tech_representation, static_representation	individual	n	instructor moves	on_design, on_analysis, on_process, references_architecture	improve_design, alternative_process, alternative_design, new-rep_draw, new-rep_tech	speech_drawing, model_manipulation
6	1.200, 1.100, 1.50	y	y	spontaneously	medium	design, communication	technical, scheme, perspective, note	plain paper, notebook, digital	lag_analysis-design, design_process, focus_images	lag_abstract-reality, static_representation	group	n	students move	principles_designing, on_process, on_design, on_representation, on_presentation, references_architecture	see_reference, improve_presentation, new-rep_model, new-rep_tech, alternative_process, see_reference, improve_design, alternative_design	speech_drawing, model_manipulation
7	1.200, 1.100, 1.50	y	y	spontaneously	medium	design	technical, scheme, perspective	plain paper, notebook, digital		static_representation	individual	n	instructor moves	on_design, principles_designing, on_construction, references_architecture, references_general		speech_drawing, draw_record, model_manipulation
8	1.200, 1.100, 1.50	y	y	spontaneously	medium	design, communication	technical, scheme, perspective	plain paper, notebook, digital		info_management, lack_perspective, static_representation, lack_drawing	group	n	students move	on_presentation, on_design, on_social, references_architecture		n
9	1.5000, 1.1000, 1.500, 1.200, 1.100	n	n								individual	y	projected	references_general, on_analysis, on_design, on_process, on_presentation	improve_analysis, improve_presentation, see_reference	n
10	1.5., 1.2, 1.1	y	y	spontaneously	low	design, communication	technical, scheme	plain paper, notebook, digital	lack_construction, instructor_approval	lack_drawing	individual	y	students move	on_construction, on_design, on_process, references_architecture, references_general	alternative_design, see_reference, improve_design, alternative_process	speech_drawing, showing_drawing
11	1,1	y	y	spontaneously	medium	design	technical, scheme	plain paper, notebook, digital	focus_images		individual	y	projected			n
12	1.500, 1.200, 1.100	n	y	spontaneously	low	study, observation, communication	perspective, scheme, note	plain paper, notebook, tracing paper	design_process, lag_analysis-design, focus_images	lag_abstract-reality, lack_perspective	individual	y	instructor moves	on_analysis, on_design, on_representation, on_approaching-site, references_architecture, on_presentation	improve_representation, see_reference, improve_analysis, improve_presentation, new-rep_draw	n
13	1.20, 1.10, 1.5	y	y	spontaneously	medium	design, communication	technical, scheme, note	plain paper, notebook, digital, tracing paper			individual	y	instructor moves	on_construction, on_design	new-rep_prototype, improve_design, alternative_design	speech_drawing, draw_record
14	1.5., 1.2, 1.1	y	y	spontaneously	low	design, communication	technical, scheme, note	plain paper, notebook, digital	instructor_approval	lack_drawing	individual	y	students move	on_design, on_approaching-site, on_process, on_construction, principles_desinging	improve_representation, improve_presentation, new-rep_prototype	hybrid_interaction, draw_record
15	1.500, 1.200, 1.100	n	y	spontaneously	low	study, observation, communication	perspective, scheme	plain paper, notebook		info_management, relate_representation, static_representation	individual	y	instructor moves	on_design, on_social, on_presentation, purposes_teaching		n
16																n
17	1.5, 1.2, 1.1	y	y	spontaneously	medium	design, communication	technical, scheme, note	plain paper, notebook, digital		info_management, relate_representation	group	y	students move	references_general, references_previous, on_design, on_process, on_construction	improve_design, alternative_process, alternative_design, new-rep_prototype, see_reference	speech_drawing, hybrid_interaction
18	1.200, 1.100, 1.50	y	y	spontaneously	medium	design, communication	technical, scheme, perspective	plain paper, notebook, digital, tracing paper		deal_scale, lack_perspective	group	n	students move			speech_drawing, model_manipulation
19	1.5, 1.2, 1.1	y	y	spontaneously	medium	design, communication	technical, scheme, note	plain paper, notebook, digital			group	y	projected			digital_drawing, hybrid_interaction, speech_drawing
20	1.500, 1.200, 1.100, 1.50, 1.10, 1.5	y	n							info_management	individual	y	projected	on_analysis, on_representation, on_presentation	new-rep_dig-model, improve_representation, improve_analysis	hybrid_interaction

			freehand_drawing						difficulties		critiques					
id	rep_scales	rep_construction	fhd	fhd_demanded	fhd_presence	fhd_what	fhd_how	fhd_where	diff_general	diff_representation	cri_setting	cri_class_review	cri_dynamics	cri_comentaries	cri_suggestions	cri_actions
21	1.200, 1.100, 1.50	n	y	spontaneously	high	study, communication	technical, perspective	plain paper	instructor_approval	deal_scale	group	n	instructor moves	on_design, principles_designing, references_architecture	alternative_design], improve_design, improve_representation, see_reference	showing_drawing, model_manipulation
22	1.1000, 1.500, 1.200, 1.100	n	n						interpret_brief instructor_approval lack_construction contour_line, different_levels	making_models, tech_representation, lack_perspective, lack_drawing, static_representation	group	n	round table	on_analysis, on_approaching-site, references_architecture	improve_analysis, improve_presentation, new-rep_model, improve_representation, see_reference	n
23																
24	1.200, 1.100	y	y	spontaneously	medium	study	technical, perspective	plain paper, notebook, tracing paper		lack_perspective, lack_drawing	group	n	instructor moves	on_design, references_architecture	improve_design, improve_representation, alternative_design	speech_drawing
25	1.5000, 1.1000, 1.500, 1.200, 1.100	n	y	spontaneously	low	communication	scheme	plain paper, cardboard, tracing paper	design_process, lack_construction	tech_representation, relate_representation	group	y	instructor moves	on_design, on_presentation	improve_presentation, alternative_design, improve_design	n
26	1.25000, 1.10000, 1.2000,	n	y	spontaneously	medium	study, communication	scheme, perspective	plain paper, tracing paper		deal_scale			students move	on_design, on_analysis, on_representation	improve_representation, see_reference	n
27		y	y	spontaneously	low	communication	technical	plain paper			group	n	instructor moves	references_architecture		n
28	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	study, communication	technical, perspective	plain paper	different_levels		group	n	students move	principles_representation, principles_presentation, on_representation, on_analysis, on_presentation, purposes_teaching, references_architecture	improve_representation, improve_presentation, alternative_process, dynamic_representation	speech_drawing, model_manipulation
29	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	design, communication	technical, note, scheme	plain paper, notebook	group_organization, interpret_brief, focus_images, design_process, using_precedents, lag_analysis-design	trans_representation, static_representation	group	n	instructor moves	purposes_teaching, on_presentation, on_representation	improve_presentation, improve_design, improve_representation, new-rep_model, alternative_design	speech_drawing, model_manipulation
30	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	communication	scheme	plain paper		static_representation, relate_representation	group	y	instructor moves	on_analysis, purposes_teaching, on_representation, on_presentation		n
31	1.500, 1.200, 1.00, 1.50	y	n						focus_images, design_process, lack_construction	tech_representation, static_representaion	group	y	online	on_design, principles_designing, principles_representation, on_representation, purposes_teaching, references_architecture	see_reference, improve_design, alternative_design	
32	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	design, communication	technical, notes, scheme	plain paper (photo), digital (3d model with notes)	lag_analysis-design, design_process, focus_images	trans_representation, tech_representation, lag_abstract-reality	group	y	online	on_representation, on_design, on_presentation, on_representation	improve_presentation, improve_representation	n
33	1.500, 1.200, 1.100, 1.50	y	y	demanded	medium	design, communication	technical, note, scheme	plain paper, notebook	lag_analysis-design, interpret_brief, design_process, focus_images, contour_line, different_levels	trans_representation, static_representation, info_management	group	n	instructor moves	on_representation, principles_designing, on_design, purposes_teaching, on_process	improve_design, alternative_process, new-rep_draw, improve_representation, dynamic_representation, new-rep_tech	speech_drawing
34	1.500, 1.200, 1.100, 1.50	y	y	demanded	medium	design, communication	technical, note, scheme	plain paper, notebook	design_process, focus_images	trans_representation, static_representation	group	n	instructor moves	on_representation, on_process, on_design	see_reference, improve_analysis, dynamic_representation, alternative_process	speech_drawing, model_manipulation
35	1.5000, 1.1000, 1.500, 1.200, 1.100	n	y	spontaneously	low	communicantion	scheme	plan paper, cardboard, tracing paper			jury	y	instructor moves	on_design, on_presentation, references_architecture	improve_presentation, improve_design	n
36																
37																
38	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	communication	perspective	plain paper (photo)			jury	y	online			
39														references_architecture		
40	1.100, 1.50, 1.20, 1.10, 1.5, 1.1	y	n						interpret_brief, lack_construction	lack_drawing, lack_perspective, static_representation, interpret_tech, info_management, deal_scale	jury	y	instructor moves	on_construction, references_general, on_presentation, principles_designing, references_architecture	improve_presentation, see_reference	n
41	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	communication	perspective	plan paper (photo)	design_process	trans_representation, tech_representation, static_representation	group	y	online	on_representation, on_presentation	improve_representation	n

			freehand_drawing						difficulties		critiques					
id	rep_scales	rep_construction	fhd	fhd_demanded	fhd_presence	fhd_what	fhd_how	fhd_where	diff_general	diff_representation	cri_setting	cri_class_review	cri_dynamics	cri_comentaries	cri_suggestions	cri_actions
42	1.200, 1.100, 1.50	n	y	spontaneously	low	communication	technical, perspective	plain paper	interpret_brief, focus_images	making_models, tech_representation, lack_perspective, lack_drawing, static_representation	group	y	round table	references_architecture, references_general, principles_representation	improve_representation, improve_design	n
43	1.5000, 1.1000, 1.500, 1.200, 1.100	n	y	spontaneously	low	communication	scheme, perspective	plain paper	design_presentation	tech_representation, lack_perspective	group	n	instructor moves	on_representation, on_presentation, on_design, principles_representation, principles_designing, purposes_teaching, references_architecture	improve_presentation, improve_representation, new-rep_model, new-rep_draw, new-rep_render	speech_drawing, model_manipulation
44	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	communication	technical, perspective	plain paper		info_management, relate_representation	group	n	instructor moves	on_presentation, on_design, references_architecture, principles_representation, principles_presentation	new-rep_draw, improve_representation, improve_presentation	speech_drawing, model_manipulation, draw_record
45	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	communication	scheme	plan paper		lack_drawing, lack_perspective	jury	n	students move	on_analysis		speech_drawing
46														references_architecture		
47	1500,	n	y	demanded	high	study, observation, communication	technical, perspective, scheme	plain paper, tracing paper, notebook			individual	y	online	on_design, references_previous, on_representation	improve_representation, alternative_design	speech_drawing
48																
49	1.200, 1.100, 1.50, 1.20	y	y	spontaneously	low	design, comunication	perspective, technical, scheme	plain paper (panel)			individual	y	online	on_construction, on_design	improve_design, alternative_design	speech_drawing
50	1.200, 1.100, 1.50, 1.20	y	y	spontaneously	low	design, comunication	perspective, technical, scheme	plain paper (panel)			individual	y	online	on_construction, on_design	improve_design, alternative_design	speech_drawing
51	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey, design	tecnhical, perspective, note	notebook, plain paper, tracing paper		relate_representation	individual	y	online	on_process, purposes_teaching, on_construction	alternative_design, new-rep_tech, alternative_process	speech_drawing, model_manipulation
52														on_representation, on_approaching-site, on_design, on_process, references_architecture	improve_design, alternative_design, alternative_process	
53	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey, design	tecnhical, perspective	notebook, plain paper, tracing paper		relate_representation	individual	y	online	on_design, on_process, on_representation	new-rep_draw, new-rep_tech, alternative_process, improve_representation	speech_drawing, digital_drawing
54	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey	technical, perspective	notebook, plain paper, tracing paper	instructor_approval	lag_abstract-reality	individual	n	instructor moves	on_representation, on_approaching-site, on_design	improve_representation, new-rep_draw, new-rep_tech	speech_drawing
55	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey	tecnhical, perspective, note	notebook, plain paper, tracing paper	instructor_approval	lag_abstract-reality, deal_scale, lack_drawing	individual	y	instructor moves	on_approaching-site, on_representation, principles_representation, on_design, principles_designing, on_process, purposes_teaching, references_architecture	improve_representation, alternative_process, visit_site, improve_design, alternative_representation	speech_drawing
56	1.1000, 1.500, 1.200	y	y	spontaneously	medium	design	technical perspective, note	notebook, plain paper, tracing paper		relate_representation, tech_representation	individual	y	online	principles_representation, principles_designing, purposes_teaching, on_process, references_architecture	improve_design, alternative_design, new-rep_model	inter_software, digital_drawing, speech_drawing, relate_representations
57	1.1000, 1.500, 1.200	y	y	spontaneously	medium	design	technical perspective	notebook, plain paper, tracing paper			individual	y	online	on_process, on_design, references_architecture, on_representation, principles_designing	improve_design, alternative_design, alternative_process, new-rep_draw, improve_representation	speech_drawing
58	1.5000, 1.2000, 1.1000, 1.500	n							lag_speech-proposal		group	y	online	on_design, on_presentation, principles_designing, on_social	improve_representation, improve_presentation, new-rep_tech, new-rep_draw	
59	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey	tecnhical, perspective	notebook, plain paper, tracing paper	design_process, contour_line, different_levels	relate_representation, lag_abstract-reality	individual	y	instructor moves	on_design, principles_designing, on_process, references_architecture	alternative_process, alternative_representation, new-rep_model	demonstration_physical, speech_drawing, relate_representations
60	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey	tecnhical, perspective, note	notebook, plain paper, tracing paper	design_process, contour_line, different_levels, instructor_approval	making_models, deal_scale	individual	y	instructor moves	on_representation, principles_representation, on_design, principles_designing, purposes_teaching	new-rep_model, alternative_process, improve_representation	speech_drawing

			freehand_drawing						difficulties		critiques					
id	rep_scales	rep_construction	fhd	fhd_demanded	fhd_presence	fhd_what	fhd_how	fhd_where	diff_general	diff_representation	cri_setting	cri_class_review	cri_dynamics	cri_comentaries	cri_suggestions	cri_actions
61	1.200, 1.100, no scale	n	y	demanded	high	study, observation, survey, design	tecnhical, perspective	notebook, plain paper, tracing paper	design_process, instructor_approval	trans_representation, static_representation	individual	y	instructor moves	on_approaching-site, on_design, principles_designing, purposes_teaching, on_construction	alternative_process, improve_representation, alternative_design	speech_drawing, model_manipulation, demonstration_physical, relate_representations
62	1.1000, 1.500, 1.200	y	y	spontaneously	medium	design	technical perspective	notebook, plain paper, tracing paper			individual	y	online	on_representation, on_design	improve_presentation, alternative_design, improve_representation	speech_drawing, model_manipulation
63	1.1000, 1.500, 1.200	y	y	spontaneously	medium	design	technical, perspective	notebook, plain paper, tracing paper			individual	y	online	on_design, references_architecture	improve_representation, alternative_design, see_reference, improve_design	speech_drawing
64	1.500,	n	y	demanded	high	study, observation, communication	technical, perspective, scheme	plain paper, tracing paper, notebook		info_management	individual	y	online	on_design, references_architecture	improve_design, alternative_design	model_manipulation, digital_drawing, speech_drawing
65	1.200, 1.100, 1.50, 1.20	y	y	spontaneously	low	design, comunication	perspective, technical, scheme	plain paper (panel)			individual	y	online	on_construction, on_design, principles_designing	improve_design, alternative_design	speech_drawing, model_manipulation
66	1.200, 1.100, 1.50, 1.20	y	y	spontaneously	low	design, comunication	perspective, technical, scheme	plain paper (panel)			individual	y	online	on_construction, on_design, on_representation, principles_representation	improve_design, new-rep_model, alternative_design	speech_drawing
67	1.200, 1.100, 1.50, 1.20	y	y	spontaneously	low	design, comunication	perspective, technical, scheme	plain paper (panel)			individual	y	online	on_construction, on_design, principles_designing	improve_design, alternative_design	speech_drawing
68	1.500,	n	y	spontaneously	high	study, observation, communication	technical, perspective, scheme, note	plain paper, tracing paper, notebook	contour_line, different_levels, instructor_approval	tech_representation, info_management	individual	n	students move	on_design, principles_designing, principles_representation, on_representation, on_process, references_architecture	improve_design, alternative_design, improve_representation, new-rep_tech	n
69																
70																
71																
72																
73																
74																
75																
76																
77																
78	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	design, communication	technical, note, scheme	plain paper, notebook	interpret_criticism, design_process, instructor_approval, focus_images, lack_construction	trans_representation, static_representation, lack_perspective, lack_drawing	group	n	instructor moves	on_design, purposes_teaching, on_representation	alternative_process, improve_design, alternative_design, new-rep_tech, new-rep_draw, visit_site	speech_drawing, model_manipulation
79	1.500, 1.200, 1.100, 1.50	y	y	spontaneously	low	design, communication	perspective, technical, note, scheme	plain paper, notebook	group_organization, focus_images, design_process, lack_construction	trans_representation, info_management, lag_abstract-reality, deal_scale, static_representation	group	n	instructor moves	on_representation, on_design, on_presentation	alternative_process, see_reference, visit_site, alternative_design, improve_design, new-rep_tech, new-rep_draw	speech_drawing
80																
81	1.5, 1.2, 1.1	y	y	spontaneously	medium	design, communication	technical, scheme	plain paper, notebook, digital	focus_images		group	y	projected			n

	ua_design_critiques															
	modes_interaction			fhd_instructors						fhd_students						
id	mod_medium	mod_intructors	mod_students	fhd_inst	fhd_inst_frequency	fhd_inst_types	fhd_inst_what	fhd_inst_how	fhd_inst_where2	fhd_sutd	fhd_stud_freq	fhd_stud_dem	fhd_stud_types	fhd_stud_what	fhd_stud_how	fhd_stud_where
1	digital	speech, gestures	speech, gestures	n						n						
2	digital	speech, gestures, digital manipulation, digital manipulation	speech, gestures, digital manipulation, prototype manipulation	n						n						
3	analogue	speech, gestures,	speech, gestures	n						n						
4	analogue	speech, gestures, drawing, model manipulation	speech, gestures, model manipulation	y	medium	technical, scheme, note	design	both	plain paper, tracing paper, students drawing	n						
5	analogue	speech, gestures, drawing, model manipulation	speech, gestures, drawing, model manipulation	y	medium	technical, scheme, note	design	both	plain paper, students drawing, notebook	y	medium	spontaniously	technical, note, scheme	design, analysis	both	plain paper, students drawing, tablet
6	analogue	speech, gestures, drawing, model manipulation	speech, gestures, model manipulation	y	medium	technical, scheme, note	design	both	plain paper, tracing paper, students drawing	y	medium	spontaniously	technical, note	design, analysis	non-manipulative	tablet, notebook
7	analogue	speech, gestures, drawing, model manipulation	speech, gestures, drawing, model manipulation	y	medium	technical, scheme, note	design	both	plain paper, students drawing, notebook	y	medium	spontaniously	technical, note, scheme	design, production	both	plain paper, students drawing, notebook, tablet
8	analogue	speech, gestures, model manipulation	speech, gestures, model manipulation	n						n						
9	digital	speech, gestures	speech, gestures	n												
10	analogue	speech, gestures, drawing, prototype manipulation	speech, gestures, drawing, prototype manipulation	y	medium	technical, scheme, note, perspective	design, production	both	plain paper, students drawing	y	medium	spontaniously	technical, note, scheme	design, production	non-manipulative	plain paper, notebook, tablet
11	digital	speech, gestures, digital manipulation, digital manipulation	speech, gestures, digital manipulation, prototype manipulation	n						n						
12	analogue	speech, gestures	speech, gestures	n						n						
13	analogue	speech, gestures, drawing, prototype manipulation	speech, gestures, drawing, prototype manipulation	y	high	technical, note, scheme	design, production	both	plain paper, notebook, students drawing	y	medium	spontaniously	technical, note, scheme	design, production	both	students drawing, tablet, tracing paper
14	digital	speech, gestures	speech, gestures	n						n						
15	analogue	speech, gestures	speech, gestures	n						n						
16																
17	both	speech, gestures, drawing, prototype manipulation	speech, gestures, prototype manipulation	y	medium	technical, note, scheme	design, production	non-manipulative	plain paper	n						
18	analogue	speech, gestures, drawing, model manipulation	speech, gestures, model manipulation	y	medium	technical, scheme, note	design	both	plain paper, tracing paper, students drawing	n						
19	both	speech, gestures, drawing, prototype manipulation	speech, gestures, prototype manipulation	y	medium	technical, note, scheme	design, production	non-manipulative	plain paper	n						
20	digital	speech, gestures	speech, gestures	n						n						

	ua_design_critiques															
	modes_interaction			fhd_instructors						fhd_students						
id	mod_medium	mod_intructors	mod_students	fhd_inst	fhd_inst_frequency	fhd_inst_types	fhd_inst_what	fhd_inst_how	fhd_inst_where2	fhd_sutd	fhd_stud_freq	fhd_stud_dem	fhd_stud_types	fhd_stud_what	fhd_stud_how	fhd_stud_where
21	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation	y	high	technical, scheme, perspective	design	non-manipulative	notebook	y	low	spontaniously	technical	design	non-manipulative	plain paper, students drawing
22	both	speech, gestures, drawing	speech, gestures	y	medium	technical, scheme	analysis, representation, presentation	manipulative	plain paper, students drawing	n						
23																
24	analogue	speech, gestures, drawing	speech, gestures	y	high	technical, scheme	design	manipulative	students drawing, tracing paper	y	low	spontaniously	technical	design, presentation	manipulative	students drawing
25	analogue	speech, gestures	speech, gestures	n						n						
26	analogue	speech, gestures, drawing	speech, gestures, drawing	y	medium	technical, scheme	design, representation	manipulative	plain paper, students drawing	n						
27	analogue	speech, gestures, drawing	speech, gestures	y	medium	scheme, note	references, presentation	non-manipulative	notebook	n						
28	analogue	speech, gestures, drawing	speech, gestures	y	medium	scheme, note	analysis, representation, presentation	non-manipulative	plain paper	n						
29	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation and transformation	y	high	technical, note, scheme, perspective	design, representation, construction	both	students drawings, notebook, plain paper, tracing paper	y	medium	spontaniously, demanded	technical, note, scheme	design	both	students drawing, plain paper
30	analogue	speech, gestures	speech, gestures	n						n						
31	digital	speech, gestures, drawing, model manipulation	speech, gestures	y	high	technical	design	non-manipulative	plain paper, notebook	n						
32	digital	speech, gestures	speech, gestures	n						n						
33	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation and transformation	y	high	technical, note, scheme, perspective	design, representation, construction	both	students drawings, notebook, plain paper, tracing paper	y	medium	spontaniously, demanded	technical, note, scheme	design, presentation	both	students drawing, plain paper
34	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation and transformation	y	high	technical, note, scheme, perspective	design, representation, construction	both	students drawings, notebook, plain paper, tracing paper	y	medium	spontaniously, demanded	technical, note, scheme	design, analysis	both	students drawing, plain paper
35	analogue	speech, gestures, model manipulation	speech, gestures	n						n						
36																
37																
38	digital	speech, gestures	speech, gestures	n						n						
39																
40	analogue	speech, gestures	speech, gestures													
41	digital	speech, gestures	speech, gestures	n						n						

	ua_design_critiques															
	modes_interaction			fhd_instructors						fhd_students						
id	mod_medium	mod_intructors	mod_students	fhd_inst	fhd_inst_frequency	fhd_inst_types	fhd_inst_what	fhd_inst_how	fhd_inst_where2	fhd_sutd	fhd_stud_freq	fhd_stud_dem	fhd_stud_types	fhd_stud_what	fhd_stud_how	fhd_stud_where
42	analogue	speech, gestures, drawing	speech, gestures	y	low	technical, scheme, note	design	non-manipulative	plain paper, students drawing	n						
43	analogue	speech, gestures, drawing, model manipulation	speech, gestures	y	high	technical, scheme, perspective	presentation, representation	both	plain paper, students drawing	n						
44	analogue	speech, gestures, drawing	speech, gestures	y	medium	scheme, note	analysis, references, presentation	non-manipulative	notebook	y	low	spontaniously	scheme, technical	analysis, presentation	non-manipulative	plain paper, students drawing
45	analogue	speech, gestures	speech, gestures, drawing	n						y	high	demanded	technical	analysis	non-manipulative	plain paper
46																
47	digital	speech, gestures, drawing	speech, gestures, drawing	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, students model	y	low	spontaniously	note, scheme	design	manipulative	students drawing, students model
48																
49	digital	speech, gestures, drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	n						
50	digital	speech, gestures, drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	n						
51	digital	speech, gestures drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, students model	n						
52																
53	digital	speech, gestures drawing	speech, gestures, drawing	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, students model	y	medium	demanded	technical, note, perspective	design	manipulative	students drawing
54	analogue	speech, gestures, drawing, model manipulation	speech, gestures, drawing	y	high	techical, note, scheme, perspective	design	manipulative	students drawing, tracing paper, plain paper	y	high	demanded	technical, note, perspective	observation, design	both	students drawing, plain paper, tracing paper
55	analogue	speech, gestures, drawing, model manipulation	speech, gestures	y	high	techical, note, scheme, perspective	design, representation	manipulative	blackboard	y	high	demanded	technical, note, perspective	observation, design	both	students drawing, plain paper, tracing paper
56	digital	speech, gestures, drawing	speech, gestures, drawign	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	y	high	spontaniously	technical, note, perspective	design	manipulative	students drawing
57	digital	speech, gestures, drawing	speech, gestures, drawign	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	y	high	spontaniously	technical, note, perspective	design	manipulative	students drawing
58	digital	speech, gestures	speech, gestures	n						n						
59	analogue	speech, gestures, drawing, model manipulation	speech, gestures	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, tracing paper, plain paper, blackboard	y	high	demanded	technical, note, perspective	observation, design	both	students drawings, plain paper, tracing paper
60	analogue	speech, gestures, drawing, model manipulation	speech, gestures	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, tracing paper, plain paper, blackboard	y	high	demanded	technical, note, perspective	observation, design	both	students drawings, plain paper, tracing paper

	ua_design_critiques														
	modes_interaction			fhd_instructors						fhd_students					
id	mod_medium	mod_intructors	mod_students	fhd_inst	fhd_inst_frequency	fhd_inst_types	fhd_inst_what	fhd_inst_how	fhd_inst_where2	fhd_sutd	fhd_stud_freq	fhd_stud_dem	fhd_stud_types	fhd_stud_what	fhd_stud_how	fhd_stud_where
61	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, tracing paper, plain paper, blackboard	y	high	demanded	technical, note, perspective	observation, design	both	students drawings, plain paper, tracing paper
62	digital	speech, gestures, drawing	speech, gestures, drawign	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	y	high	spontaniously	technical, note, perspective	design	manipulative	students drawing
63	digital	speech, gestures, drawing	speech, gestures, drawign	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	y	high	spontaniously	technical, note, perspective	design	manipulative	students drawing
64	digital	speech, gestures, drawing	speech, gestures, drawing	y	high	techical, note, scheme, perspective	design, representation	manipulative	students drawing, students model	y	low	spontaniously	note, scheme	design	manipulative	students drawings, students models
65	digital	speech, gestures, drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing							
66	digital	speech, gestures, drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing	n						
67	digital	speech, gestures, drawing	speech, gestures	y	high	techical, note, scheme, perspective	design, construction	manipulative	students drawing							
68	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation	y	high	technical, note, perspective	design	both	students drawing, tracing paper	y	high	spontaniously	technical, note, perspective	design	both	students drawing, tracing paper
69																
70																
71																
72																
73																
74																
75																
76																
77																
78	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation and transformation	y	high	technical, note, scheme, perspective	design, representation, construction	both	students drawings, notebook, plain paper, tracing paper	y	medium	spontaniously, demanded	technical, note, scheme	design, analysis	both	students drawing, plain paper
79	analogue	speech, gestures, drawing, model manipulation and transformation	speech, gestures, drawing, model manipulation and transformation	y	high	technical, note, scheme, perspective	design, representation, construction	both	students drawings, notebook, plain paper, tracing paper	y	medium	spontaniously, demanded	technical, note, scheme	design, analysis	both	students drawing, plain paper
80																
81	both	speech, gestures, prototype manipulation	speech, gestures, prototype manipulation	n						n						

Appendix 3 Drawing as a historical record

The table presented here refers to the data collected and analyzed in Chapter 5, section 5.5.

date	period	arch_marker	title	program	students	figure	available	elements	type	num_elements	captions	rendering	filled_back	background	constructive	line
1873	first	1874.T.001	Design for a Country Depot employing wood, iron, brick, and stone	infra	Dowse, William Baldwin	1	y	multiple	elevation, section, plan	4	y	real	n	real	n	hard
1877	first	1877.T.003	Town Hall	admin	Capen, George Walter	3	y	multiple	elevation, plan	3	y	real	y	abstract	n	hard
1877	first	1877.T.004	Town Hall	admin	Capen, George Walter	4	y	multiple	elevation, section, plan, perspective	5	y	real	y	real	n	hard
1877	first	1877.T.005	Fire Engine House	assist	Chamberlin, William E.	2	y	multiple	elevation, plan, detail	5	y	real	y	abstract	n	hard
1878	first	1878.T.001	Town Hall	admin	Baker, Charles M.	7	y	single	perspective	1	n	real	y	real	n	hard
1878	first	1878.T.003	Design for a Scientific Acadamy	cultural	Eaton, Charles S.	6	y	multiple	elevation, section, plan	6	y	real	y	abstract	n	hard
1878	first	1878.T.005	Museum of Fine Arts and Library	cultural	Higgins, Alfred S.	5	y	multiple	elevation, plan, detail	4	y	real	y	abstract	n	hard
1881	first	1881.T.001	Design for a Bank Building	finance	Wilkes, Charles M.	8	y	multiple	elevation, section, plan, detail	9	y	real	y	abstract	y	hard
1885	second	1885.T.001	Design for a Theater	cultural	Benton, Edward R.	9	y	single	elevation	1	y	real	y	abstract	n	hard
1885	second	1885.T.002	Design for a Theater	cultural	Homer, Eleazar Bartlett	10	y	single	section	1	n	n	y	n	n	hard
1885	second	1885.T.003	Design for a Theater	cultural	Homer, Eleazar Bartlett	11	y	single	plan	1	y	n	y	n	n	hard
1886	second	1886.T.001	Elevated Railway Station	transport	Brainerd, William L.	12	y	single	elevation	1	y	real	y	abstract	n	hard
1886	second	1886.T.002	Elevated Railway Station	transport	Brainerd, William L.	13	y	single	plan	1	y	n	y	n	n	hard
1887	second	1887.T.001	Design for a College	education	Gay, Joseph B.	14	y	multiple	elevation, plan	2	y	real	y	abstract	n	hard
1888	second	1888.T.001	[A Reformatory Prison]	prision	Bates, Henry D.	15	y	multiple	elevation, section	2	n	real	y	real	n	hard
1888	second	1888.T.002	[A Reformatory Prison]	prision	Bates, Henry D.	16	y	multiple	plan	4	y	n	y	abstract	n	hard
1888	second	1888.T.003	Design for a Court House and Jail	prision	Fuller, James Edward	17	y	multiple	elevation, section	2	y	real	y	abstract	n	hard
1889	second	1889.T.001	A Quarantine Hospital	service	Edwards, Arthur V.	18	y	multiple	elevation, section, plan	6	y	real	y	abstract	n	hard
1889	second	1889.T.004	A Marine Aquarium	cultural	Hooker, Richard	19	y	multiple	section, plan	3	n	real	y	abstract	n	hard
1889	second	1889.T.007	A Museum of Natural History	cultural	Kilham, Walter H.	20	y	multiple	elevation, section	2	y	real	n	real	n	hard
1890	second	1890.T.001	[Plumbing System for a City House]	housing	Alden, Jr., Charles H.	21	y	single	section	1	y	n	n	n	y	hard
1890	second	1890.T.005	A College of Music	education	Emery, Elwood A.	22	y	multiple	elevation, section	2	y	real	y	real	n	hard
1890	second	1890.T.006	A College of Music	education	Emery, Elwood A.	23	y	single	plan	1	n	real	y	real	n	hard
1890	second	1890.T.009	Chamber of Commerce	admin	Nims, Norman G.	24	y	single	perspective	1	n	real	y	real	n	hard
1891	second	1891.T.001	A College Memorial Building	memorial	Clement, Hugh B.	25	y	single	elevation	1	y	real	n	real	n	hard
1891	second	1891.T.006	A National Opera House	cultural	Lawrence, William H.	26	y	single	elevation	1	n	real	n	abstract	n	hard
1891	second	1891.T.007	A National Opera House	cultural	Lawrence, William H.	27	y	single	plan	1	n	real	y	abstract	n	hard
1891	second	1891.T.009	A Metropolitan Post Office	service	Leeming, Woodruff	28	y	single	elevation	1	n	real	n	abstract	n	hard
1891	second	1891.T.010	A Metropolitan Post Office	service	Leeming, Woodruff	29	y	single	section	1	y	real	n	abstract	n	hard
1892	second	1892.T.002	A Club House	housing	Dennet, William Hartley	30	y	single	elevation	1	n	real	y	abstract	n	hard
1892	second	1892.T.005	An Official Residence	housing	Feland, Logan	31	y	multiple	plan	3	y	real	y	abstract	n	hard
1892	second	1892.T.006	A Technical High School	education	Francis, Frederick C.	32	y	multiple	elevation, section	2	y	real	y	abstract	n	hard
1892	second	1892.T.009	Design for an Amory	military	Gill, Edward P.	33	y	multiple	elevation, section	2	n	real	y	abstract	n	hard
1892	second	1892.T.012	An Office Building	office	Hopkins, Prescott A.	34	y	multiple	elevation, section	2	n	real	y	abstract	n	hard
1892	second	1892.T.013	An Office Building	office	Hopkins, Prescott A.	35	y	multiple	plan	4	y	real	y	abstract	n	hard
1894	second	1894.T.001	[Public Library]	cultural	Dickey, Charles W.	36	y	single	elevation	1	n	real	y	abstract	n	hard
1894	second	1894.T.002	[Public Library]	cultural	Dickey, Charles W.	37	y	single	plan	1	n	real	y	abstract	n	hard
1894	second	1894.T.003	[Public Library]	cultural	Dickey, Charles W.	38	y	single	section	1	n	real	y	abstract	n	hard
1894	second	1894.T.007	[An Art Museum]	cultural	Harrison, Burt S.	39	y	single	section	1	n	real	n	real	n	hard
1894	second	1894.T.018	A Country Museum & Reading Room	cultural	Lowell, Guy	40	y	single	elevation	1	n	real	y	abstract	n	hard
1894	second	1894.T.018.01	A Country Museum & Reading Room	cultural	Lowell, Guy	41	y	single	section	1	n	real	y	abstract	n	hard
1896	second	1896.T.001	[A Freeport of Boston]	infra	Bourne, Frank Augustus	42	y	single	plan	1	n	real	y	real	n	hard
1896	second	1896.T.002	[A Freeport of Boston]	infra	Bourne, Frank Augustus	43	y	single	plan	1	y	real	y	real	n	hard
1896	second	1896.T.004	[A Small Court House]	housing	Bucher, Russell S.	44	y	single	frontal	1	n	real	y	real	n	hard
1896	second	1896.T.007	[Police & Fire Station]	assist	Cannon, Lewis T.	45	y	single	frontal	1	n	real	y	abstract	n	hard
1896	second	1896.T.012	[A College Building]	education	Chenery, Winthrop Holt	46	y	single	plan	1	n	real	y	abstract	n	hard
1896	second	1896.T.052	[Hunting Lodge]	private	Scofield, Donald C.	47	y	single	frontal	1	n	real	n	real	n	hard
1897	second	1897.T.001	Monumental Entrace to River Tunnel	infra	Beers, Herbert P.	48	y	single	frontal	1	n	real	y	real	n	hard
1897	second	1897.T.004	[Country Inn]	private	Cutler, William H.	49	y	single	plan	1	n	real	y	real	n	hard
1897	second	1897.T.005	[Mortuary Chapel]	religious	Dodge, Edwin S.	50	y	single	plan	1	n	real	y	real	n	hard
1897	second	1897.T.006	[Mortuary Chapel]	religious	Dodge, Edwin S.	50-2	y	single	section	1	n	real	y	abstract	n	hard
1897	second	1897.T.018	[Gothic Church]	religious	LeBaron, Frederick N.	51	y	single	elevation	1	n	real	n	real	n	hard
1897	second	1897.T.025	[A terminal for a Railroad Station]	infra	Rooke, Warren A.	50-3	y	single	plan	1	n	real	n	real	n	hard
1898	second	1898.T.001	[Savings Bank in a Large City]	finance	Alexander, Donald N.	52	y	single	elevation	1	n	real	y	abstract	n	hard
1898	second	1898.T.002	[Savings Bank in a Large City]	finance	Alexander, Donald N.	53	y	single	plan	1	n	real	y	abstract	n	hard
1898	second	1898.T.004	[American Villa]	housing	Burnham, George	54	y	single	frontal	1	n	real	y	abstract	n	hard
1898	second	1898.T.014	[House Near City for Gov. General]	housing	Davis, Huntly W.	55	y	single	plan	1	n	real	y	abstract	n	hard
1901	second	1901.T.001	A Country Residence	housing	Aldrich, William T.	56	y	single	frontal	1	n	real	y	real	n	hard
1902	second	1902.T.032	A Railroad Station	infra	Wellman, Walter J.	57	y	single	frontal	1	y	real	n	abstract	n	hard
1903	second	1903.T.009	Art Institute	cultural	Gibson, Jessie G.	58	y	single	frontal	1	n	real	y	real	n	hard
1903	second	1903.T.010	Art Institute	cultural	Gibson, Jessie G.	59	y	single	elevation	1	n	real	y	real	n	hard
1907	second	1907.T.030	Synagogue	religious	Marx, Samuel	60	y	single	frontal	1	n	real	y	real	n	hard
1913	second	1913.T.023	A Railroad Station for a Capital City	infra	Franklin, Paul J.	61	y	multiple	section	2	n	n	y	real	n	hard
1913	second	1913.T.030	[College Chapel]	religious	Glidden, Henry O.	62	y	single	frontal	1	n	real	y	real	n	hard
1913	second	1913.T.032	[College Chapel]	religious	Glidden, Henry O.	63	y	single	section	1	n	real	y	real	n	hard
1913	second	1913.T.033	[College Chapel]	religious	Glidden, Henry O.	64	y	single	plan	1	n	real	y	real	n	hard
1913	second	1913.T.054	A Modern Bank Building	finance	Redfern, Philip T.	65	y	single	elevation	1	n	real	y	abstract	n	hard
1914	second	1914.T.028	An Estate in Southern California	housing	Kennedy, Frederick H.	66	y	single	frontal	1	n	real	y	real	n	hard
1914	second	1914.T.029	An Estate in Southern California	housing	Kennedy, Frederick H.	67	y	single	plan	1	n	real	y	real	n	hard
1915	second	1915.T.012	[Banking Institution]	finance	Byrnes, Benjamin H.	68	y	multiple	section, plan	3	y	real	y	abstract	n	hard

date	period	arch_marker	title	program	students	figure	available	elements	type	num_elements	captions	rendering	filled_back	background	constructive	line
1915	second	1915.T.013	[Banking Institution]	finance	Byrnes, Benjamin H.	69	y	single	frontal	1	n	real	y	abstract	n	hard
1915	second	1915.T.017	A Small Museum	cultural	Fowle, Donald Adams	70	y	single	frontal	1	n	real	y	real	n	hard
1915	second	1915.T.102	A Design for a Bank and Office Building	finance	Schoeppe, Edward	71	y	multiple	elevation, section	2	n	real	y	abstract	n	hard
1915	second	1915.T.121	A Civic Center for a New England City	admin	Whitten, Jr., Francis	72	y	single	plan	1	y	real	y	real	n	hard
1916	second	1916.T.033	A Hunt Club in Maryland	private	Fisher, Jr., David K. Este	73	y	single	frontal	1	y	real	y	real	n	hard
1916	second	1916.T.034	A Hunt Club in Maryland	private	Fisher, Jr., David K. Este	74	y	multiple	section	2	y	real	n	real	n	hard
1916	second	1916.T.086	Open-Air Chapel for a Tuberculosis Sanitarium	religious	Phelps, Charlotte L.	75	y	single	frontal, detail	1	y	real	y	n	n	hard
1920	second	1920.T.020	Commercial Building	commercial	Wilson, Charles T.	76	y	multiple	elevation, perspective	2	y	real	y	real	n	hard
1920	second	1920.T.021	Commercial Building, tower detail	commercial	Wilson, Charles T.	77	y	single	frontal	1	y	real	y	real	n	hard
1923	second	1923.T.002	A Chapel for a Residence	religious	Adelberg, Ida B.	78	y	multiple	frontal, plan	2	n	real	y	real	n	hard
1923	second	1923.T.003	[Chapel for a Residence]	religious	Berla, Julian E.	79	y	multiple	section	2	n	real	n	abstract	n	hard
1924	third	1924.T.001	[Automobile Branch Plant]	commercial	Baxter, Helen F.	80	y	single	plan	1	y	n	y	abstract	n	hard
1924	third	1924.T.002	[Automobile Branch Plant]	commercial	Baxter, Helen F.	81	y	multiple	elevation, section	2	n	real	y	abstract	n	hard
1924	third	1924.T.003	[Automobile Branch Plant]	commercial	Baxter, Helen F.	82	y	multiple	elevation, section	2	n	real	y	abstract	n	hard
1925	third	1925.T.014	A Railroad Station	infra	Peterson, Charles E.	83	y	multiple	elevation, plan, section	3	n	real	y	real	n	hard
1926	third	1926.T.002	A Hall for Entertainment	cultural	Beckwith, Herbert Lynes	84	y	multiple	frontal, plan, section	3	n	real	y	real	n	hard
1926	third	1926.T.015	Hall for Entertainment	cultural	Herreshoff, Norman F.	84-2	y	multiple	frontal, plan, section	3	n	real	y	real	n	hard
1926	third	1926.T.039	[An Island Commercial Center]	commercial	Walquist, John Albert	85	y	multiple	elevation, section	2	y	real	y	real	n	hard
1926	third	1926.T.040	[An Island Commercial Center]	commercial	Walquist, John Albert	86	y	single	elevation	1	n	real	y	real	n	hard
1926	third	1926.T.041	[An Island Commercial Center]	commercial	Walquist, John Albert	87	y	single	frontal	1	y	real	y	real	n	hard
1927	third	1927.T.010	A Small Bank	finance	Buckingham, Katharine	88	y	single	frontal	1	n	real	y	real	n	hard
1927	third	1927.T.011	A Small Bank	finance	Buckingham, Katharine	89	y	multiple	section, plan	2	y	real	y	abstract	n	hard
1928	third	1928.T.013	Office Building	office	Hunn, Robert W.	90	y	single	frontal, section, plan	4	y	real	y	real	n	hard
1929	third	1929.T.026	Masonic Temple	religious	Rich, Howard L.	91	y	single	frontal	1	n	real	y	real	n	hard
1930	third	1930.T.011	A Counry Inn	private	Harmon, Albert H.	92	y	single	frontal	1	y	real	y	real	n	hard
1931	third	1931.T.001	A Post Office	service	Abrahamson, Nigil S.	93	y	multiple	frontal, section, plan	4	y	real	y	real	n	hard
1931	third	1931.T.006	A Moving Picture House	cultural	Cutter, William Bowman	94	y	single	frontal	1	y	real	y	real	n	hard
1931	third	1931.T.010	A Post Office in a Winter Resort	service	Hammond, George Ross	95	y	multiple	frontal, section, plan	4	y	real	y	real	n	hard
1931	third	1931.T.015	A Post Office	service	Moffat, Robert Reid	96	y	multiple	frontal, section, plan	4	y	real	n	real	n	hard
1931	third	1931.T.017	A Post Office	service	Parker, John Albert	97	y	single	frontal	1	n	real	y	real	n	hard
1933	forth	1933.T.001	A Typical Aircraft Plant	industry	Brown, William Hoskins	98	y	multiple	elevation, plan	2	y	real	y	real	n	hard
1933	forth	1933.T.007	Brewery and Beer Garden	industry	Bunshaft, Gordon	99	y	multiple	elevation, plan	2	y	real	y	real	n	hard
1933	forth	1933.T.008	Brewery and Beer Garden	industry	Bunshaft, Gordon	100	y	multiple	elevation, section	2	y	real	y	real	y	hard
1933	forth	1933.T.009	Brewery and Beer Garden	industry	Bunshaft, Gordon	101	y	multiple	plan, detail	4	y	n	n	n	y	hard
1935	forth	1935.T.029	A Center for Architecutral Crafts for Metropolitan Boston	education	Bunshaft, Gordon	102	y	multiple	elevation, plan, perspective	4	y	real	n	real	n	hard
1938	forth	1938.T.057	Design of a Flexible System for Roadside Restaurants	private	Weese, Harry M.	103	y	multiple	elevation, plan, perspective	6	y	stylized	n	real	n	hard
1938	forth	1938.T.058	Design of a Flexible System for Roadside Restaurants	private	Weese, Harry M.	104	y	multiple	section, plan, perspective	5	y	stylized	n	real	y	hard
1938	forth	1938.T.059	Design of a Flexible System for Roadside Restaurants	private	Weese, Harry M.	104-2	y	multiple	section, plan	5	y	n	n	n	y	hard
1938	forth	1938.T.060	Design of a Flexible System for Roadside Restaurants	private	Weese, Harry M.	104-3	y	multiple	plan, section, perspective	5	y	stylized	n	n	y	hard
1938	forth	1938.T.061	Design of a Flexible System for Roadside Restaurants	private	Weese, Harry M.	105	y	multiple	photo, slice	4	y	n	n	n	y	hard
1940	forth	1940.T.140	Standardized Propaganda Units: No. 1 Relationship	private	Pei, I. M.	106	y	multiple	elevation	2	y	n	n	n	y	hard
1940	forth	1940.T.141	Standardized Propaganda Units: No. 2 Plan	private	Pei, I. M.	106-2	y	single	plan	1	y	n	n	real	n	hard
1940	forth	1940.T.142	Standardized Propaganda Units: No. 3 Elevations	private	Pei, I. M.	107	y	single	elevation	1	y	stylized	n	real	n	hard
1940	forth	1940.T.143	Standardized Propaganda Units: No. 4 Color	private	Pei, I. M.	108	y	multiple	detail	3	y	n	n	n	y	hard
1940	forth	1940.T.144	Standardized Propaganda Units: No. 5 Details	private	Pei, I. M.	109	y	multiple	detail	6	y	n	n	n	y	hard
1940	forth	1940.T.145	Standardized Propaganda Units: No. 6 Details	private	Pei, I. M.	109-2	y	multiple	plan, sketch	6	y	n	n	real	n	hard, free-ha
1940	forth	1940.T.146	Standardized Propaganda Units: No. 7 Flexibility	private	Pei, I. M.	109-3	y	single	photo	1	y	n	n	n	n	n
1943	forth	1943.T.063	An Abbattoir Meat-Packing Plant in Baghdad Iraq	industry	Meer, Yusf	110	y	multiple	elevation	3	y	n	n	n	n	hard
1943	forth	1943.T.064	An Abbattoir Meat-Packing Plant in Baghdad Iraq	industry	Meer, Yusf	111	y	multiple	detail	8	y	n	n	n	y	hard
1944	forth	1944.T.051	Calcutta University Library	education	Rahman, Habibur	112	y	single	plan	1	y	n	n	n	y	hard
1944	forth	1944.T.052	Calcutta University Library	education	Rahman, Habibur	113	y	multiple	elevation	2	y	n	n	n	n	hard
1950	forth	1950.T.094	Highway Motel System	private	Hamilton, Richard W.	114	y	multiple	elevation, plan	5	y	stylized	n	n	y	hard
1950	forth	1950.T.095	Highway Motel System	private	Hamilton, Richard W.	115	y	multiple	elevation, plan	4	y	stylized	n	n	y	hard
1950	forth	1950.T.096	Highway Motel System	private	Hamilton, Richard W.	116	y	single	plan	1	y	n	n	real	n	hard
1950	forth	1950.T.097	Highway Motel System	private	Hamilton, Richard W.	117	y	single	slice	1	y	n	n	n	y	hard
1950	forth	1950.T.098	Highway Motel System	private	Hamilton, Richard W.	118	y	single	sketch	1	y	stylized	n	real	n	free-hand
1950	forth	1950.T.099	Highway Motel System	private	Hamilton, Richard W.	119	y	single	map	1	y	n	n	n	n	hard
1950	forth	1950.T.101	Highway Motel System	private	Hamilton, Richard W.	120	y	multiple	map	2	y	n	n	n	n	hard
1950	forth	1950.T.102	Highway Motel System	private	Hamilton, Richard W.	120-2	y	single	plan	1	y	n	n	real	n	hard
1951	forth	1951.T.081	Seminary for the Xaverian Missionary Fathers	regilious	Cavanaugh, William J.	121	y	single	plan	1	y	stylized	n	real	n	hard
1951	forth	1951.T.082	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	122	y	single	plan	1	y	n	n	real	y	hard
1951	forth	1951.T.083	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	123	y	multiple	elevation	5	y	stylized	n	real	n	hard
1951	forth	1951.T.085	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	124	y	single	perspective	1	y	stylized	n	real	n	hard
1951	forth	1951.T.086	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	125	y	multiple	plan, perspective	2	y	stylized	n	n	y	hard
1951	forth	1951.T.087	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	126	y	multiple	section, plan, detail	4	y	n	n	n	y	hard
1951	forth	1951.T.088	Seminary for the Xaverian Missionary Fathers	religious	Cavanaugh, William J.	127	y	multiple	detail	4	y	n	n	n	y	hard
1952	forth	1953.T.119	Low Multi-Family Housing : A Neighborhood Nucleus for Mattapan	housing	Kniskern, John P.	129	y	multiple	elevation, plan	5	y	stylized	n	n	n	hard
1953	forth	1953.T.118	Low Multi-Family Housing : A Neighborhood Nucleus for Mattapan	housing	Kniskern, John P.	128	y	single	sketch	1	y	stylized	n	real	n	free-hand
1956	forth	1956.T.044	World Trade Center for Boston	admin	Fawcett, Mary S.	130	y	multiple	elevation	2	y	n	n	real	n	hard
1959	forth	1959.T.165	Town Community for the Navajo Tribe	housing	Wilmsen, Edwin N.	131	y	single	plan	1	y	n	n	real	n	hard