

Digital Sketching and Architecture Education

Leyla Alipour^{1,2}, Punik Simoni³

¹ School of Architecture, College of Fine Arts, University of Tehran, Iran
leila.alipour@ut.ac.ir

² Department of Curriculum and Pedagogy, Faculty of Education, University
of British Columbia, Vancouver, Canada

³ Faculty of Architecture and Urban Planning, Iran university of Art, Tehran,
Iran

Abstract. This study investigates the components affecting the choice of design tools in the ideation phase of architectural design, with a particular focus on students' reluctance toward sketching. Through an open inquiry, we gathered insights from architecture students, educators, and practitioners on their preferences, experiences, and perceptions of tool selection. Our results show that tool preference in ideation is not only shaped by the inherent advantages and disadvantages of sketching or Computer-Aided Design (CAD) but also by personal characteristics, educational frameworks, and contextual dynamics. Rather than positioning tools in opposition, the results suggest that sketching and digital tools support different modes of engagement within this communicative process. Findings indicate that the optimal ideation tool varies by individual context, suggesting that effective design education should address diverse student needs, enabling a balance between digital proficiency and foundational sketching skills.

Keywords: Design Ideation, Sketching, CAD Tools

1 Introduction

Ideation is an important step in the design process. There are some techniques and tools to facilitate the ideation process. Traditional tools such as sketching and hand drawing methods remain widely used, while digital tools have rapidly advanced and increasingly replace pencil and paper in the ideation process. Theorists discuss that designers interact with their drawings and develop ideas through this engagement [1].

Design tools participate in the interactive system of communication [2] and actively shape and are shaped by cognitive and creative processes [3].

The process of sketching is possible in both hand drawing and computer-aided design (CAD) tools. There are different and often conflicting opinions about the impact of CAD tools on the design process, especially on the creativity. Some studies argue whether digital tools effectively support the creative process. To address this, empirical research has often compared the use of different tools and evaluated creativity based on criteria such as the number of generated design ideas [4,5], originality [6], and form-related limitations [7]. However, only a limited number of studies move beyond evaluating tool characteristics and instead focus on designers and their relationships with tools and environments. In this regard, a few studies briefly point to important dimensions such as communication [8], cognition [9], and creative behaviour [10], which require further investigation.

Considering the role of tools in design education and the importance of design ideation, this study aims to identify the components influencing the use of ideation tools (hand sketching and digital tools) in architectural design, with a particular focus on students' choice. Unlike previous studies that compare tools, this research adopts a general perspective by exploring the role of multiple components through the experiences of students, educators, and graduates.

Although a substantial body of literature compares hand sketching and digital tools, much of that research relies on experimental or comparative approaches and focuses on measurable outcomes. Given the complexity of the ideation process, this study adopts an exploratory qualitative approach to capture broader aspects such as students' emotions, beliefs, personal experiences, and the influence of educational and cultural contexts. Data were collected through open-ended responses from architecture students, educators, and graduates working in professional practice. Participants were asked about their use of sketching in design and the reasons behind students' reluctance toward hand sketching in the ideation phase. The responses were analyzed to develop a multidimensional understanding of how ideation tools support design thinking and what components shape the process.

2 Literature review

2.1 Sketching in Design Ideation

The creation of design ideas is one of the important and most effective steps of the design process. Previous studies have provided evidence that sketching enables

designers to rapidly produce multiple ideas and explore relationships, patterns, and possibilities [11]. Theorists have identified hand sketching as a fundamental tool in design, supporting processes of seeing, acting, and thinking [12,13]. Designers use sketches to talk to themselves, communicate with their ideas and develop them [14,15]. In other words, sketching helps designers to explore new possibilities that may not have been imagined beforehand [16].

Schon argued that designers interact with their sketching to develop ideas through a process he described as reflection-in-action [1,15]. Similarly, other researchers have shown that designers interpret their sketches to find a way to improve their ideas and take next steps [17]. Empirical studies have demonstrated the benefits of sketching and confirmed sketching assists ideation [18,19], helps designers to think about design problem [20], and enables communication with the members of design teams [18].

In addition, sketching allows designers to explore new ways of thinking, develop ideas, and generate alternatives [16]. Sketching is accessible, quick, and reinterpretible [21]. Researchers have also shown that sketching supports active memory [22], and save ideas for future use [11,14]. In other words, designers have some ideas and goals when they begin sketching but they can find new goals and new forms in their sketches, while creating new sketches, they record the process in the drawings [14].

Sketching can be performed through both hand drawing and digital tools. Despite its recognized role in design thinking, some design students do not fully appreciate sketching and may choose to skip this stage [23]. Some researchers studied the reasons for the reluctance of students and found that students wanted to make a perfect and flawless sketch in the first try, so they stuck to techniques of drawings. Some students think sketching is useless in their future profession and some others don't have required skills. Students may also feel anxious about being judged or compared to others [24]. Additional studies have linked sketch inhibition to skill-set deficiency, social anxiety and previous negative educational experience and its symptoms include reluctance to engage, deferral to other tools and poor-quality design output [23].

While sketching functions as a form of communication within the design process, it is often evaluated as a final output rather than as a process. Evidence suggests that educators may prioritize the quality of drawing over the quality of ideas, and sketches that are not well presented may not be judged fairly [19]. One key skill required for sketching is the ability to understand and apply perspective, which many students find

challenging [25]. Background studies have also shown a relationship between three-dimensional imagination and the tendency to use sketching, indicating that students with stronger visual skills are more likely to engage in it [26].

Despite its advantages, hand sketching is sometimes replaced by digital tools such as CAD. This raises an important question: can different tools play the same role in design thinking and in the communication between designers and their ideas? Rather than assuming the superiority of one medium over another, it becomes necessary to examine how different tools contribute to ideation and how designers engage with them within the ideation process.

2.2 Comparing Different Tools in Design Ideation

Researchers and developers have increasingly focused on designing and evaluating tools to support ideation processes. While some studies emphasize the technical capabilities and affordances of tools (e.g., [27]), others investigate the cognitive dimensions of design thinking and interaction (e.g., [28]).

We reviewed the empirical studies that explored the tools in design in different context of architecture e.g. [29], industrial design e.g. [8], product design e.g. [30], and graphical design e.g. [4]. A large portion of this literature adopts a comparative approach, often contrasting hand drawing and digital tools with the aim of identifying which better supports creativity. However, these studies report mixed and sometimes contradictory findings.

Some studies assess creativity based on the number of design ideas generated. For instance, they explored which tool supported creating more design ideas and alternatives [4,5]. Others evaluate novelty and originality, for example Wojtczuk and Bonnardel [6] compared the physical model making and 3D digital modelling and found that undo ability of computer tools help designers to create concepts with aesthetic and originality attributes. Some studies [7] have examined whether tools hinder the process of form finding, particularly in terms of how students adapt their ideas to the limitations and capabilities of specific tools. Others [5] have highlighted the potential of tools to assist designers in discovering new features and generating a wider range of form combinations. However, some researchers [31] briefly noted that designers need to remain creative throughout the process, emphasizing the role of the designer rather than the tool, although this point has not been further elaborated.

Beyond outcome-based comparisons, some studies investigate how tools influence cognitive processes and design behaviour. Robertson and Radcliffe [8] recognized the positive effects of CAD tools are imagination and communication and negative effects

consist of premature fixation, circumscribed thinking and bounded ideation. Yamamoto and Nakakoji [32] investigated human-computer interaction in the first level of the design process, by focusing on the cognitive process of the designer's mind and proposed that digital tools must develop in creative interaction and not in practicality [32]. Additional research focuses on problem understanding and functional communication [33].

Therefore, much of the existing literature covers a binary comparison of digital versus hand drawing tools. As a result, it remains unclear how tools contribute to different aspects of the design process, or how they might be combined purposefully to support idea generation and communication. This limitation suggests the need for a broader conceptual framework that moves beyond tool comparison and instead examines design ideation as an interactive process.

2.3 Design Ideation as a Conversational System

Design tools do not support design in a linear manner; instead, they participate in an interactive system of meaning-making. Glanville [2] argues that design is a conversational, constructivist, and non-deterministic process rather than a linear problem-solving activity. In this view, a conversation occurs between the designer and their sketches, through which ideas are externalized, interpreted, and transformed. This perspective frames design as a form of communication and action [34]. Based on this theory, Fischer [3] conceptualizes tools as active participants that both shape and are shaped by cognitive and creative processes. Accordingly, tools can be analysed not simply by their functional capabilities, but by their degree of restriction, level of ambiguity, and structure of feedback that influence the nature of the design conversation [28].

By considering design as a conversational process in which actions, representations, and interpretations continuously inform one another, rather than as a linear sequence of problem-solving steps [34], studying the use of design tools requires consideration of the broader context, particularly the designer's cognition and emotional states. Iordanova et al. [9] highlight the role of students' emotions and engagement during the design process, emphasizing how interaction with tools affects cognitive involvement. Similarly, Dawoud et al. [10] demonstrate that creative behaviour is shaped by the interaction between designers and digital tools, particularly through experiential components such as flow.

From this perspective, ideation emerges through continuous interactions between designers, tools, and context, where each element both influences and is influenced by

the others. This interpretation aligns with the second-order cybernetic view of design proposed by Glanville [2] and further developed in design research by Fischer [3,28], in which design is understood as a conversational and constructivist process. In this view, meaning is not transmitted through tools but constructed through recursive feedback loops between the designer and their representations. Building on these theoretical perspectives and empirical studies, in this research we consider design ideation as a conversational system of design cognition, in which multiple interacting components co-evolve. Within this system, the choice and use of tools cannot be understood in isolation but depend on the relationships between these components.

3 Methodology

We asked the opinion of people involved to the architecture design education of some different schools of architecture in Iran. Using open-ended questions allows participants to express their perspectives in their own terms and enables the identification of unexpected themes and relationships that may not be investigated before. Participants include architecture students, teachers, and graduated students. The selection of community of participants is not random but based on our overall access to the society of architecture. We asked students “among different mediums for ideation step of design, which tool do you prefer to learn and use and why?” and “why are the students reluctant to sketch?” We also asked teachers and graduated students a similar question “what is the role of sketching in learning architecture?” and “why are the students reluctant to sketch?”

We tried to collect opinions of as many numbers of participants as possible and received more than 200 responses. Because the questions are open-ended, the responses are varied between 4 words to more than 1000 words for one participant. The final amount of received text is more than 40.000 words. We read and coded the text manually in several rounds. At first one coder found 345 themes and another found more than 400 themes and there were a lot of differences between the codes. We had some sessions of discussion that resulted merging similar codes into 67 codes and categorizing the themes into 10 categories. We continued coding with the use of ATLAS.ti, the application designed to assist qualitative methodology.

4 Qualitative Results

Participants expressed a variety of ideas. Figure 1 shows the four main components and six other components of their relationship.

- We found that some of the discussions are focused on the students. They discussed the students' emotions, beliefs, and skills.

For example a junior student stated: *"Actually, the feeling of reluctance always arises in my mind when sketching, which I think the reason is the lack of self-confidence and lack of belief in my own abilities, and sometimes the feeling of competition and weakness compare to those who we think are better than us and have more experience. But when I know more about the subject or have a better understanding of it, it can help me to draw more. Sometimes I get an obsessive feeling that I want to do the work better when drawing and I keep erasing so that a better sketch comes out, but this constant erasing and not making a definite decision about the work sometimes discourages me, which causes quitting."*

- Some of the discussion directly related to the tools. People talked about the practicality, ideation capacity, the quality of outcome, and the accessibility of tools.

For example a sophomore student said: *"for the beginning of design, I am not reluctant to sketch. Manual drawing can be useful in the beginning of design because it gives freedom of action to the person and does not have the framework of the CAD tools, but after the initial stages, if the software comes into work, it can fix many of the problems of the design and makes us faster."*

- In some other parts, participants discussed the system of education of architecture, public education, or the teachers.
- Some parts of explanations related to the context and environment including the profession of architecture, environment, and society.
- In addition to these four main components (tools, students, education and contextual dynamics), we can recognize some discussion about relationship between components two by two. Therefore, we have six other categories, including the relationship between the student and the tool, the relationship between education and the student, the relationship between the contextual dynamics and the education, the relationship between the contextual

dynamics and the tool, the relationship between the tool and the education, and the relationship between the student and the contextual dynamics (Figure 1).

Students talked about their interaction with tools and shared their emotions while using the tools. One talked about the emotions of frustrations, and distraction:

"Despite a clear idea in the mind, its presentation frustrates me in the first place, and it disappoints me. If I don't get the pleasant result immediately, I give up the effort and give up my idea. Sometimes I am satisfied with a low quality idea because I cannot present my idea. It needs a lot of time and patience to strengthen hand drawing skills, which I think is a very difficult task at this time because there are so many tools that cause distraction most of the time."

And the other one talked about the cognition and connection:

"For me, I usually begin designing with holding the pen in my hand. By drawing the first line, I feel that I am one step closer to my mental fantasy. The faint lines overlap and the image gradually becomes clear, an image that has the taste of reality. Maybe this comes from my interest in painting and drawing since childhood. The world of drawing and colouring is a place of imagination for me."

Some students also described using a mix of hand sketching and computer tools during idea generation. For example, one student said:

"I use hand sketches to start a drawing idea because it gives me more freedom and I can put the ambiguity in my mind on paper and interpret it in many ways. It's the beginning of more ideas. Whenever an idea starts to take shape in my mind and find form, I put that idea into the computer and draw it, which gives me more control over the form and the 3D perspective. This way I can better decide whether to put it aside or continue. Sometimes I print the same computer perspective and draw it by hand and change it. Because some manual changes produce faster and more ideas."

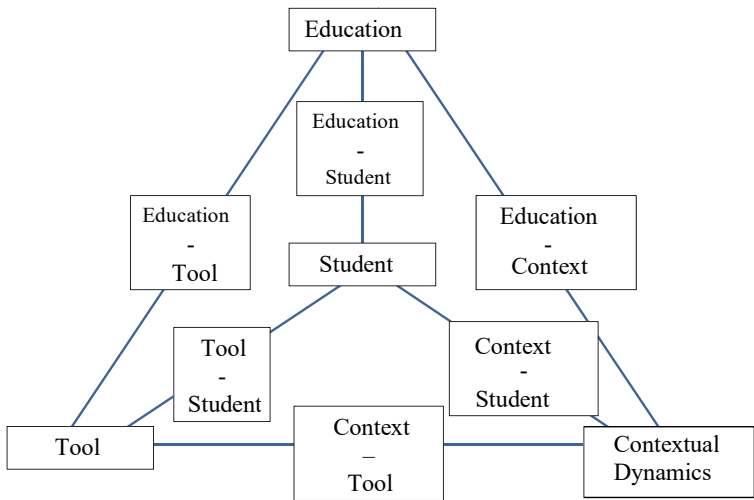


Fig.1. Themes

5 Quantitative Results

Table 1 presents the most cited codes, indicating those mentioned by more than 15 percent of the participants. Based on this table, it is evident that more than 40 percent of participants discussed various aspects of shortcoming in skills. They highlighted that one of the reasons students are reluctant to sketch is their inability in drawing or creating images from their imagination. Following this, they recognized the importance of sketching and expressed enjoyment in the process, also mentioned its beneficial role in ideation.

Additionally, the code referring to diverse capabilities and features of Computer-Aided-Design (CAD) tools is mentioned by 30 percent of participants. It's noteworthy that these five most cited reasons belong to different categories.

By categorizing the codes into 10 distinct categories, we can now compare the quantity of each category. Table 2 displays the count and percentage of each category overall and across three participants groups. According to the table, the “students” category has received more attention overall. Upon closer examination, it appears that student themselves discussed this category more than other participant groups. Meanwhile, teachers showed interest in both the “students” and “education” categories, while architects predominately focused on the “tools” category.

Table 1. Codes with the highest frequency

Codes	Count	Percent
Lack of drawing skills	84	42%
Difficulty in transforming thoughts into images	80	40%
Importance and enjoyment of sketching	77	38%
Benefits of sketching in ideation	65	32%
The capabilities of CAD tools	64	32%
Limited time for sketching	40	20%
CAD updates and widespread use	38	19%
Feelings of frustration, weakness, and discomfort	37	18%
Challenges of sketching, including time consumption	36	18%
Necessity of more practices	36	18%
Lack of self-confidence, conservatism, and courage issues	33	16%
Lack of ideation ability and fear of generating bad ideas	33	16%
The relationship between hand and mind in sketching	32	16%
The impact of the digital era on sketching practices	31	15%
Worries about sketching and its outcomes	30	15%

Table 2. The frequency of each category between three groups

Code	All		Teachers		Students		Architects	
	202 participants		38 participants		124 participants		40 participants	
Tool	156	77%	25	66%	93	75%	38	95%
Students	167	83%	29	76%	108	87%	30	75%
Education	93	46%	27	71%	48	39%	18	45%
Contextual Dynamics	49	24%	17	45%	23	19%	9	23%
Students-Tools	111	55%	13	34%	72	58%	26	65%
Education-Students	72	36%	15	39%	44	35%	13	33%
Education- Context	45	22%	14	37%	23	19%	8	20%
Tools-Context	56	28%	21	55%	25	20%	10	25%
Education-Tools	84	42%	21	55%	51	41%	12	30%
Students- Context	12	6%	5	13%	5	4%	2	5%

Furthermore, when students were asked about their feelings towards using sketching during the design process, a variety of responses emerged. Some students answered affirmatively, expressing reluctance, while others responded negatively, indicating no reluctance at all. Additionally, some participants provided mixed responses, expressing a somewhat ambivalent sentiment (Table 3).

Upon analysing the data, it became apparent that those who admitted to feeling reluctant mostly offered explanations centred on personal factors influencing their hesitation. Conversely, among those who stated no reluctance and actively utilized sketching, the reasons predominantly revolved around the capability of the tools in the design process.

Table 3. The differences between codes mentioned by three groups of students

	Yes			No			No answer		
	70			71			23		
	count	percent	correlation	count	percent	correlation	count	percent	correlation
Tools	50	71%	0.29	61	86%	0.37	20	87%	0.13
Students	68	97%	0.41	56	79%	0.31	12	52%	0.07
Education	27	39%	0.19	36	51%	0.26	13	57%	0.12
Context	10	14%	0.09	15	21%	0.14	8	35%	0.12
Tools- Students	36	51%	0.25	49	69%	0.37	13	57%	0.11
Tools- Education	29	41%	0.22	27	38%	0.20	9	39%	0.09
Tools- Context	10	14%	0.09	18	25%	0.17	7	30%	0.10
Students- Education	29	41%	0.25	22	31%	0.18	7	30%	0.08
Students- Context	3	4%	0.04	3	4%	0.04	1	4%	0.03
Education- Context	15	21%	0.15	11	15%	0.10	5	22%	0.08

5.1 Students

The “students” category emerged as the most cited factor, with a total of 437 codes related to students. These codes encompass various aspects of architecture students’ abilities and personalities that influence their inclination towards using sketching. The information can be classified into three sub-categories, Emotions, Beliefs, and Skills.

Under the Emotions sub-category, students’ feelings and fears were expressed including feeling frustrated, weak, and unpleasant, lacking motivation, fearing a bad idea, fearing drawing, time constraints, seeking comfort and avoiding effort, exhibiting laziness, being perfectionists, conservative, lacking courage, self-confidence, focus, and determination.

Beliefs encompass what students think or certain misconceptions they hold. For instance, some students believe that CAD is perfect and flawless, drawing must be beautiful, and they should learn sketching rapidly or have prior skills.

Additionally, students’ skills and abilities were a significant topic of discussion. Participants mentioned a lack of skill in hand drawings, 3D visualization, or generating ideas and creativity. They also discussed skills directly or indirectly related to sketching, such as drawing skills or time management skills.

Among these codes, Table 4, the lack of drawing skills received the most attention. This factor was discussed extensively by all three participant groups: teachers,

students, and architects. Following that, the inability to convert ideas into images was the second most mentioned code, predominantly cited by the students themselves. Hence, it appears that students perceive their main challenge as the skill of effectively translating their ideas into visual expression. Apart from the most cited codes, the table reveals that students expressed their fears, such as the fear of a bad idea or fear of judgment. Teachers, on the other hand, discussed students' lack of imagination and visual thinking skills and their false assumption that CAD is flawless.

Table 4. The frequency of codes in the category of Students

Code	All 202 participants		Teachers 38 participants		Students 124 participants		Architects 40 participants	
Lack of drawing skills	84	42%	17	45%	49	40%	18	45%
Lack of the skill of transforming mind into image	80	40%	11	29%	55	44%	14	35%
Feeling frustrated, weak and unpleasant	37	18%	5	13%	29	23%	3	8%
Lack of self-confidence, Conservatism, Lack of courage	33	16%	6	16%	24	19%	3	8%
Lack of ideation ability and fear of a bad idea	33	16%	6	16%	25	20%	2	5%
Weakness in 3D visualization	28	14%	7	18%	15	12%	6	15%
Fear of being judged	25	12%	5	13%	19	15%	1	3%
Seeking comfort and avoiding effort and labor, laziness	23	11%	6	16%	12	10%	5	13%
Being product oriented and hasty to gain outcome	22	11%	6	16%	13	10%	3	8%
The lack of motivation	15	7%	4	11%	8	6%	3	8%
Misconception of the need to draw beautifully	14	7%	3	8%	11	9%	0	0%
Being a perfectionist	12	6%	1	3%	10	8%	1	3%
The need to have a complete and perfect idea	10	5%	3	8%	7	6%	0	0%
False assumption that CAD is perfect and flawless	8	4%	5	13%	2	2%	1	3%
Misconception of learning sketching very fast	5	2%	2	5%	2	2%	1	3%
Presuming the need for previous preparation, skill, or special talent	4	2%	1	3%	2	2%	1	3%
Lack of time management skills	4	2%	0	0%	3	2%	1	3%
Students	437							

5.2 Tools

In total, our participants mentioned explanations related to “tools” category 387 times. Two important aspects of tools stood out: the benefits of sketching for ideation and capabilities of the CAD tools.

According to Table 5, the advantages of sketching in the ideation step were predominantly highlighted by architects. Interestingly, students also emphasized this factor more than any other. On the other hand, architecture teachers primarily focused on those features that CAD provides for design process. They specifically mentioned that CAD is fast, accurate, simple to use, provides different perspectives and dimensions, allow unlimited corrections, and offer various outputs.

Moreover, Architects discussed that CAD offers a more professional outcome, while sketching has certain limitations, such as inaccuracy, limited numbers of outputs, and unsuitability for complex forms.

In total, some of the codes were related to advantages and disadvantages of sketching in different stages of design process including ideation, concept development, correction and output.

Table 5. The frequency of codes in the category of tools

Codes	All 202 participants		Teachers 38 participants		Students 124 participants		Architects 40 participants	
Benefits of sketching in Ideation	65	32%	2	5%	42	34%	21	53%
The capabilities of CAD	64	32%	12	32%	39	31%	13	33%
Sketching is hard and time consuming	36	18%	7	18%	23	19%	6	15%
The relationship between hand and mind	32	16%	3	8%	21	17%	8	20%
Disadvantages of lack of drawing skills in ideation	26	13%	4	11%	19	15%	3	8%
Unsatisfactory outcome of sketching	26	13%	3	8%	19	15%	4	10%
Professional outcome of CAD	26	13%	5	13%	11	9%	10	25%
CAD hinders the mind	24	12%	3	8%	16	13%	5	13%
Limitations in sketching in form creations, and numbers of concepts or outcomes	23	11%	2	5%	11	9%	10	25%
Sketching is not usable for design development step	20	10%	1	3%	14	11%	5	13%
Special forms or processes need special tools	13	6%	2	5%	6	5%	5	13%
Physical mode-making capabilities	11	5%	0	0%	9	7%	2	5%
Sketching needs expensive instruments	9	4%	2	5%	5	4%	2	5%
Sketching is available and handy	8	4%	1	3%	16	13%	1	3%
Limitation of sketching for ideation	4	2%	0	0%	3	2%	1	3%
Tools	387							

Indeed, some of the data collected pertains to the relationship between tools and students, Table 6. For instance, there were participants who expressed that sketching is an enjoyable activity and students are aware of its significance in the design process. On the other hand, teachers pointed out that for some architecture students, sketching and drawing may be perceived as something unfamiliar and foreign.

Table 6. The frequency of codes in the category of Students-tools

	All		Teachers		Students		Architects	
	202 participants		38 participants		124 participants		40 participants	
Sketching is important and enjoyable	77	38%	6	16%	51	41%	20	50%
Being worried about sketching and its results	30	15%	2	5%	22	18%	6	15%
Sketching is unfamiliar and strange	16	8%	6	16%	8	6%	2	5%
Feeling more comfortable in oral presentation of idea	7	3%	0	0%	6	5%	1	3%
Students-Tools	130							

5.3 Education

Participants also engaged in discussions related to the educational system 186 times, which included aspects such as curriculum, the knowledge and behaviour of teachers, and the methods of design education. Notably, based on Table 7, the most frequently cited aspect of education was the importance of informing students about sketching and discussing the various steps of the design process.

Table 7. The frequency of codes in the category of Education

	All		Teachers		Students		Architects	
	202 participants		38 participants		124 participants		40 participants	
Informing students about the concept and reasons of sketches	29	14%	14	37%	14	11%	1	3%
Professors' behaviour at the classroom	26	13%	8	21%	12	10%	6	15%
Negative changes in the educational program	25	12%	10	26%	11	9%	4	10%
Sketching as inseparable part of design	23	11%	4	11%	14	11%	5	13%
Evaluating ideas based on the rendering of the sketches	21	10%	4	11%	13	10%	4	10%
Teachers are product-oriented	20	10%	1	3%	17	14%	2	5%
Professors' point of view or skills	17	8%	8	21%	5	4%	4	10%
Determining which tool to use at which point	15	7%	1	3%	12	10%	2	5%
Lack of proper updating in the curriculum	10	5%	3	8%	7	6%	0	0%
Education	186							

Teachers also expressed concerns about how recent changes in the education program impact sketching practices. On the other hand, students mostly voiced complaints about teachers solely prioritizing the final product rather than

emphasizing the creative process. Moreover, the focus on mastering design tools seemed to be perceived as a dominant educational objective.

Architects also shared their perspectives, highlighting how certain teachers' behaviours negatively influenced their enthusiasm for sketching during their own student days. They pointed out behaviours indicative of a competitive environment or attitudes of disregard towards specific students.

Concerning the relationship between students and education, it is evident from Table 8 that all three participant groups emphasize the importance of students dedicating more practice and effort to enhance their sketching abilities. Specifically, they highlighted the need for students to gain more experience and practice in visualization and imagination. This aspect appears to be a significant concern across the board. Moreover, both students and architects raised concerns about the time limitations within the educational system. On the other hand, teachers discussed the issue of students' confusion in selecting a suitable sketching tool for their design work.

Table 8. The frequency of codes in the categories of Students-education and Tools-education

	All		Teachers		Students		Architects	
	202		38		124		40	
	participants		participants		participants		participants	
Necessity of more practices	36	18%	7	18%	24	19%	5	13%
Limitation in time	21	10%	2	5%	14	11%	5	13%
Lack of skills in using knowledge	15	7%	4	11%	11	9%	0	0%
Confusion and necessity of choosing one tool	14	7%	6	16%	6	5%	2	5%
Necessity of reviewing architecture examples	11	5%	2	5%	8	6%	1	3%
Students- Education	97							
Lack of enough time for sketching	40	20%	11	29%	24	19%	5	13%
The shortcoming in sketching education	29	14%	10	26%	16	13%	3	8%
Too much mandatory practices	19	9%	4	11%	13	10%	2	5%
False creativity in CAD, Bad ideas with good presentation	15	7%	3	8%	9	7%	3	8%
Sketching is hard and time consuming to learn	15	7%	5	13%	8	6%	2	5%
CAD is easy to learn	8	4%	2	5%	6	5%	0	0%
Tools- Education	126							

Regarding the relationship between education and tools, two main codes emerged: *the lack of time allocated for teaching sketching* and *the shortcomings in sketching education itself*. Participants pointed out that due to time constraints, there might not be sufficient opportunity to adequately teach and develop sketching skills. Additionally, when discussing the shortcomings in sketching education, participants

mentioned that the current methods primarily revolve around drawing and rendering. As a result, students who lack prior experience in drawing may struggle to improve their skills effectively within the current educational approach.

5.4 Contextual Dynamics

The culture and the society have a significant impact on the practice of sketching, with the prevailing digital era being a crucial influence affecting all aspects of life. Participants also noted that sketching is not widely accepted in professional practice (Table 9).

Table 9. The frequency of codes in the category of Contextual Dynamics

	All		Teachers		Students		Architects	
	202 participants		38 participants		124 participants		40 participants	
The digital era	31	82%	10	8%	19	48%	2	1%
Sketching is not appropriate in the profession	20	53%	9	7%	4	10%	7	3%
The necessity of CAD to enter the profession or continue studying abroad	13	34%	6	5%	5	13%	2	1%
Contextual Dynamics	64							

When exploring the relationship between contextual dynamics and students (Table 10), several codes emerged. The rush of time and the consequent lack of focus and determination were identified as factors that influence students' lives and personalities. Additionally, participants discussed how digital tools are continuously updated and perceived as more suitable in today's contextual dynamics, while sketching is considered out-dated. Furthermore, the abundance of advertisements and recommendations related to digital tools contributes to their dominance. These codes fall under the context-tools category.

Moreover, discussions arose about the effects of other related education, such as public education before university or after-school classes. Participants also mentioned the negative impact of university entrance exams that are unrelated to architecture. These codes were categorized under the relationship between education and contextual dynamics. Among the codes in this category, the most frequently cited one pertained to the negative effects of side education, such as private institutes for drawing and sketching or services focused solely on success in one exam rather than fostering a comprehensive skillset.

Table 10. The frequency of codes in the categories of Student-Contextual Dynamics, Tools-Contextual Dynamics, and Education-Contextual Dynamics

	All		Teachers		Students		Architects	
	202 participants		38 participants		124 participants		40 participants	
The rush of time and lack of focus and determination	8	4%	3	8%	4	3%	1	3%
The effect of senior students	5	2%	2	5%	2	2%	1	3%
Student-Context	13							
CAD is update and common	38	19%	15	39%	16	13%	7	18%
CAD is exciting and recommended	21	10%	12	32%	6	5%	3	8%
sketching is old and out of date	13	6%	5	13%	8	6%	0	0%
Tools-Context	72							
The negative effect of side education	25	12%	7	18%	12	10%	6	15%
The problem in public education	19	9%	6	16%	11	9%	2	5%
Enter into the university through unrelated exam	13	6%	7	18%	6	5%	0	0%
Education- Context	57							

6 Discussion

Students, architecture teachers, and architects discussed their preferences between digital and hand-drawing tools for ideation, as well as the reasons for students' reluctance toward sketching. In response to the primary question of whether students are reluctant to sketch, the results were nearly evenly split. Approximately half of the students expressed reluctance, while the other half showed no hesitation, with a smaller proportion providing no clear answer. Overall, the findings indicate that the interactions between key components, namely the student, education, the tool, and contextual dynamics, influence the choice and use of ideation tools.

The most frequently cited component was the student, highlighting the importance of emotions, beliefs, and skills. These findings emphasize the central role of the designer in the ideation process. In line with the theoretical perspective adopted in this study, and drawing on Glanville [2] and Fischer [3,28], the results suggest that the focus should not be limited to the qualities of tools but rather extended to designers. More than 40% of participants referred to skill-related challenges, particularly focusing on students' inability to draw or create images from their imagination. Other skills, such as ideation and time management, were also mentioned. Consistent with previous research, reluctance toward sketching is associated with fear of producing imperfect work, lack of skill, and the belief that sketching is irrelevant to future professional practice [24], as well as anxiety about being judged by others [23]. The importance of imagination skills is further supported by studies showing a direct

relationship between three-dimensional visualization ability and motivation to sketch [25].

Compared to similar studies, we found a broader range of student beliefs, such as the notion that CAD is perfect and flawless, that drawing must be beautiful, and that they should learn sketching quickly or already have prior skills. In addition, this research identified more emotions, including frustration, lack of motivation, fear of generating poor ideas, time pressure, avoidance of effort, and lack of confidence or focus. These findings highlight the cognitive and affective dimensions of the design process. Rather than being secondary effects, such emotions can be understood as regulatory mechanisms within ideation, shaping how students engage with tools, respond to ambiguity, and shift between exploratory and controlled modes of thinking. For example, students experiencing uncertainty or low confidence may prefer digital environments that provide structure and immediate feedback, whereas those more comfortable with ambiguity may engage more readily in sketch-based exploration. Moreover, different stages of the design process, such as initial brainstorming, exploratory idea generation, idea formulation, and evaluation, require different levels of ambiguity, control, and feedback. As a result, students can move between these tools to match these needs, and in some cases combine them.

Our results also showed that the characteristics and benefits of the tools can influence the selection. Participants identified positive aspects of sketching, such as assisting with ideation, provide a stronger connection with the mind, and its accessibility and convenience. Positive aspects of CAD tools included their speed, accuracy, ease of use, ability to provide different perspectives and dimensions, allowance for unlimited corrections, and production of various outputs and professional results. Participants also mentioned some negative aspects of sketching, such as limitations in accuracy, a restricted number of outputs, unsuitability for complex forms, and the need for expensive instruments. Similarly, negative aspects of CAD tools were identified, including digital tools force the use of specific forms. These perceived advantages and limitations can be interpreted through Fischer's framework [3] in terms of degrees of ambiguity, control, and feedback within the design process.

In the literature, there is a substantial body of knowledge on the benefits and shortcomings of both categories of design tools (e.g., [20]) yet remains characterized by conflicting conclusions. Some studies emphasize the benefits of hand drawing for creativity [4,7], while others highlight the advantages of digital tools [4,6,30]. This contradiction is also evident in the present findings. Rather than resolving this debate by privileging one category over the other, the results suggest that the effectiveness of tools cannot be understood in isolation from other component specially designer's cognition and emotion.

An important finding of this study is the significance of the student-tool relationship. We found that some participants mentioned sketching as enjoyable and felt comfortable with hand drawing, while others, particularly teachers, noted that students accustomed to digital tools find hand sketching unfamiliar and strange. This relationship plays a critical role in shaping tool preference. Although a limited number of previous studies have briefly pointed to this relationship, for example through concepts such as communication, cognitive engagement, or flow experience [9,10,31], these aspects have typically been treated as secondary observations, while the primary focus has remained on the capabilities and characteristics of tools. In contrast, our study places this relationship at the center of the analysis. From this perspective, design ideas emerge through the interaction between the designer and the tool as a medium of thinking. As argued by Fischer [3], designers do not simply use tools as designed; rather, they employ them in ways that may be unpredictable and extend beyond their original purpose. Within this interaction, both the designer and the tool are continuously transformed, shaping one another through a recursive process. In this sense, design outcomes can be understood as the result of this evolving relationship.

Education, including curriculum structure, teaching methods, and instructors' perspectives, was another major component identified, mostly by teachers. Participants emphasized the role of sketching within the curriculum, as well as the influence of instructors' attitudes and classroom practices. Meanwhile, students complained that professors care more about the final product than the process, evaluating presentations instead of ideas. Architects also noted that negative educational experiences led to a lack of interest in hand sketching. The findings highlight the need for continuous development of curricula and teaching methods to better support sketching skills and ideation practices. We also found that, in the relationship between students and education, students expressed a need for more practice. Regarding the relationship between education and tools, the amount of time allocated for learning sketching, the type and amount of practice, and the difficulty of learning to sketch were frequently mentioned. These observations align with previous studies addressing negative educational experiences [23], evaluation biases [19], and assessment practices [6]. In addition, the results show that students' engagement with tools is shaped by how design processes are taught, evaluated, and valued, emphasizing the idea that tool use is not an individual preference but a pedagogically constructed practice.

Regarding contextual dynamics, students primarily mentioned that the digital era plays a crucial role in their choice of tools. Other factors included the privilege of CAD tools in the profession, the widespread use of computers, positive attitudes toward new technology, and contextual issues that may affect education, such as entrance

exams and supplementary education. Findings may vary across different contexts based on cultural and other characteristics, but the dominance of new technology in various aspects of life remains a common theme.

Another insightful finding is the differing perspectives among participant groups. Students primarily focused on their own limitations, often attributing difficulties to lack of skills and challenges in expressing ideas, suggesting a need for stronger support in visual expression. Teachers, while acknowledging these skill gaps, emphasized educational structures and the importance of guidance. Architects, in contrast, focused mainly on the functional aspects of tools, with less emphasis on educational influences or cognitive development.

Overall, the findings suggest that ideation in design education cannot be adequately explained through a linear relationship between tools and outcomes. Instead, student characteristics, educational structures, tool properties, and contextual conditions operate as interdependent components within a dynamic and recursive system of design cognition. In this sense, the study does not merely confirm previously identified variables; rather, it demonstrates how these components interact within a relational system of co-construction. Moving beyond the conventional dichotomy between hand drawing and digital tools, sketching and CAD can be understood as different modes of engagement within a cognitive communication system. Ideation emerges from the ability to navigate between conditions such as ambiguity and structure, and exploration and control, rather than from reliance on any single tool.

7 Conclusion

There are various technics that designers can use in the ideation stage of designing. One of the strongest is sketching, which can be done by hand or digitally. Some architecture students are reluctant to use hand sketching, preferring to skip it. The preference for sketching tools and the reasons behind this choice vary. Based on our results, it is not only the advantages and limitations of the tools that influence the decision, but also the characteristics of the students, their teachers, and the context. Therefore, the ideal design tool can differ for each person in each context. Our results suggest that students need to develop more skills in using design tools and improving their imagination, which can be achieved through practice and gaining experience.

There is significant controversy over whether certain tools hinder or enhance creativity. Ultimately, it is the designer who use the tools in a creative way. The choice of tools depends largely on which tool the designer feels more comfortable with, which, in turn, depends on their experience and character. For individuals who grew

up using tablets without ever using a pencil, it can be difficult to draw ideas on paper, making them more inclined to rely on digital tools. As a result, progress in digital tools should focus on enabling designers to remain creative rather than operating at a technical level.

In education and context, there is still a lack of acknowledgment of differences among designers, while the design process itself should be more central than the final presentation of an idea. This study highlights the open-ended nature of the interactions between different components, showing that design decisions, including tool selection, are shaped by the connections between these components rather than by any single one.

An important outcome of this study, compared to similar research, is shifting the focus from simply comparing tools toward understanding ideation as a process shaped by the interaction between different components. Tools are not only technical instruments but also part of the thinking process, influencing how designers engage with their ideas. This perspective also helps explain the contradictory findings in previous studies, as the effectiveness of each tool depends on how it is used, by whom, and in which context. Therefore, the value of a tool cannot be understood independently, but should be considered in relation to the designer, the educational setting, and the overall design process.

Future studies could further explore the relationship between students (as designers) and ideation tools to better understand how this interaction impact creativity, learning processes, and tool preference over time. Building on the theoretical framework of this study, particularly second-order cybernetics and the concept of design as a form of communication, further research may investigate how designers and tools co-evolve through continuous interaction, and how meaning is constructed through this process. In this sense, future studies could examine more closely how different tools support or constrain this communication, and how designers engage with them as part of a conversational system. Additionally, research could examine the future applications of emerging technologies in architectural design, including new AI tools. While it is still unclear how AI will impact education and the profession, these tools are likely to significantly transform the design process.

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