

The Role of the Hand in the Architectural Design Process: Insights from Bahrain

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Abstract

Until recently, architectural design and drawings relied almost entirely on hand works from sketching to final drawings. However, today, the use of hand in architectural design is declining, even when research shows its undiminished effectiveness. Hand includes varied methods, such as sketching, modelling, and tracing paper layering. This decline is worrying especially given the fact that the work emanating from modern technologies are not becoming better, but poorer. In this context, this research examines the role of the hand in the architectural design process.

The study explored the frequency of use of hand and digital methods in each design stage by the students following the five-year Bachelor of Architecture program at the department of architecture at the university of Bahrain, as well as their effect on the final design quality, to ascertain the role the hand plays in the overall design process. A survey was administered to 18 students, followed by an assessment of designs produced by 6 students as case studies.

Findings show that the usage of hand and physical means is getting reduced with each stage on average as they progress from the first year onwards, the maximum being at conceptualisation; In fact, digital methods had a larger presence in each stage. Despite the lower usage, most students also admitted that physical methods enhanced their designs and enabled more potent ideas to unravel. It is recommended to teach the students how to integrate the hand work better into current design practice.

Keywords: Architecture, Design Process, Computer-Aided Design (CAD), Hand Sketching, Modelling.

Introduction

Until recently, architectural design used to be produced entirely by hand, manually drawing plans and creating physical models. However, with the introduction of easily accessed CAD software in the 80's, architecture practice has slowly shifted to computer drawing. Such differences make the choice well-justified, but are these the only differences there are?

Research has shown that physical work and media engage the brain more than digital ones. For example, research proves that reading literacy, an intellectual and creative process, is stronger when reading from print than when reading from a digital device (Wu & Peng, 2016). This suggests that the mere physicality of the text and its existence in a book engages the senses and enhances the cognitive process. Moreover, physically doing an action or engaging it with our senses also impacts other functions, like memory or perception (Kiefer & Trumpp, 2012). Embodied cognition as a whole is an increasingly popular theory which details that cognitive

function is intricately related to our sensorimotor processing (Wilson, 2002; Farina, 2021). Considering this, a question arises: does the use of the hand improve the creative process involved in designing? And do the usage of physical media and employment of the hand channel different ideas?

Currently, the University of Bahrain teaches first- and second-year design courses with hand drafting, and third year onwards use exclusively computer-aided design for final design presentation, which deters the students from designing physically to ensure efficiency in their work. The researcher examines the current design activities in different years and different stages of design.

This research aims to improve the design process and help it reach its optimal form, which would help all architects achieve creative solutions to their design problem. The objectives of this study are:

- to examine the frequency of usage of hand-driven methods in comparison to digital methods in different design stages,
- to identify the role of the hand in design,
- to recommend changes to current university design activities to meet architectural students' needs based on findings.

Theoretical Background

The architectural design process has many definitions. Some consider design as a journey that begins with an idea and attempts to solve “multi-variable concerns” in the architect’s head (Khakzand & Rakhshani, 2024). At the same time, design knowledge is a form of “knowing in action”, Schön (1992) argues. “It is mainly tacit, in several senses of the word: designers know more than they can say, they tend to give inaccurate descriptions of what they know, and they can best (or only) gain access to their knowledge in action by putting themselves into the mode of doing”. In other words, design is a lived experience.

The American Institute of Architects (AIA) categorizes the professional design process into three phases: schematic design, design development, and construction documents. Due to this research taking place in a university setting, the design studio courses studied do not cover the construction/technical drawings stage, so it will not be considered in this paper. With regards to the first two stages, other architects split it into smaller phases. For example, architect Michael Graves (2012) considers these three design phases: the referential sketch (conceptualization), the preparatory study (schematic design), and finalized design (design development). This research will be going forward with these three phases.

The design process takes place through either physical or digital media. In this case, physical media refers to freehand sketches made by pencil or pen, drawings on paper and tracing paper, manual drafting with a t-square, and physical models made by wood, foamboard, clay, paper, or any other physical material, whereas digital media refers to computer-aided design (CAD) techniques of all kinds, ranging from 2D and 3D CAD software like AutoCAD and ArchiCAD, building information modelling (BIM) systems such as Revit, 3D modelling software like SketchUp and Rhino, to analysis software used for specific tasks such as Forma and Vasari. Many architects, such as Zumthor and Lewis, Tsurumaki, and Lewis, prefer a hybrid approach playing to the strengths of both mediums (Brillhart, 2013). Regardless, young students are increasingly abandoning the manual workflow and sticking to CAD software only.

The reality is that CAD is not an equivalent to physical work; it is its own thing, separate entirely, enforcing certain trains of thought and utilizing different ways to design (Pallasmaa, 2009). Here, we attempt to outline some of the major differences between the two modes of designing, considering what current CAD technologies do not replicate from the process.

First of all, sketches and drawings on paper have an inherent vagueness to them, where they leave a gap open to interpretation. This allows viewers, even the architect himself, to re-evaluate and imagine what is left in that gap, thus stimulating the imagination and giving the work an artistic quality. For example, architect Rob Miners explains that “sketches allow

flexibility, since they don't require the same level of precision as a computer, and something that you initially thought would be 15 cm (6 in.) wide can easily be reinterpreted as 20 cm (8 in.) wide" (Jones, 2019, pp. 7-8). James Wines (2020) tackles it from another direction, where congested lines, irrelevant references, and ink that drips off the pen can suddenly give rise to new ideas in what he calls a 'subliminal accident'. This imprecision and potential for reinterpretation is also present in physical study models, granting the architect space for his creativity to take place. A few designers have tried creating software for vague sketching to modeling processes on computers, but they are still in the testing phase (Rasoulzadeh et al, 2024; Dorsey et al, 2007).

Another thing to consider is that designing manually is done by an accumulation of hand drawings on tracing paper. It can switch between different levels of detail on the fly, and whenever an architect would like to change something, he would layer a new tracing paper on top of the previous one and redraw it all, changing the design in subtle ways (Heumann, 2012). Computational design is much more linear and faster, and such changes are heavily discouraged. This gives rise to the idea of premature fixation: when the computer design is created with heavy information too quickly, it discourages the designer from exploring other solutions (Walther et al, 2007; Veisz et al, 2012). In a way, the limitations of physical media make them more flexible.

As mentioned in the introduction, embodied cognition is the theory that the cognitive function is intricately related to our sensorimotor processing, which many architects believe affects their design work, where it is enhanced by working physically, connecting the mind, eye, and hand. This connection triangle is intuitive and natural. For instance, research suggests that gestures reduce the load on cognition and working memory (Hostetter & Bahl, 2023). Applied into architecture, Park et al (2020) find that depending on the complexity of a spatial test, more gestures were naturally created, and in the mental transformation test for architects, the more frequent the gestures, the faster the response time for test takers.

The act of designing by models or sketches is also the medium through which design ideas are conceived and created (Suwa et al, 1998). Mark West (2020, pp. 27-29) describes the materiality of the pencil and paper 'seen' and felt by his hand, which transports him to a space where images take form and become "perfectly clear", similar to how you would see images in clouds after focusing. Pallasmaa (2009) also discusses this at length, as he reasons that the existence of the models and drawing in the same physical and material world as the building and architect exist in results a haptic and multi-sensory imagination, enriching the designs. In comparison, computer drawings happen in a scale-less world and without a tactile connection, creating designs that have no connection to our three-dimensional world (Brillhart, 2013; Pallasmaa, 2009). Both the motions of the hand as well as its existence in our physical world influence architectural designs. Although many are exploring gesture-based modeling in computers for more intuitive designing, they still have not reached the level of sophistication required for actual use (Heumann, 2012). All in all, it is clear the design process by hand is quite different from the process by computer.

Review of Literature

Although many studies attempt to consider the effect of these manual or digital workflows in design, the results often focus on one type only. Olukoya & Kuti (2015) illustrate the prevalence of CAD software as well as its benefits from the users' point of view in their survey, but do not touch upon sketching or modelling activities. Conversely, Ulme and Elere (2023) show that most students value their fine art and sketching studies, and many utilise freehand sketching to communicate with colleagues and clients. However, they do not compare this practice with digital drawing. Amitabh (2021)'s implementation of an advanced hand graphics course was also met with positive feedback from students.

Here, Ekhaese et al (2017)'s more balanced approach explores the usage of both media in design, where it can be seen that most students frequently use freehand sketching, verbal communication, and CAD tools to present immature ideas. Moreover, many students specified that their designs would be the same no matter what they use, although a few also mentioned

negative effects from CAD that they try to avoid. As for specific design stages, students and lecturers have a large preference for CAD over manual drafting in the technical drawings stage, with the exception of drawings created from site visits (Fakhry et al, 2021).

Qualitative case studies effectively explore the differences between the tools as well. Groleau et al (2012) investigate the friction between the aesthetic sense of the older generation's preferred hand drawing and the efficiency and viability of 3D renderings in an architecture firm in depth. Veisz et al (2012), on the other hand, document a mechanical engineering team's design process between sketching and CAD to their final result, showing that overreliance on CAD at the conceptual stage causes premature fixation and a less efficient design, contrasting with it increasing the design's efficiency and effectiveness at later stages.

In the field of experimental research, researchers use multiple measuring tools. Several researchers compare between the two mediums in their effect on spatial ability, which is a known identifier for engineering success (Maeda & Yoon, 2011). Results show that spatial ability can be enhanced by both physical (Leopold et al, 2001) and CAD tools (Kösa & Karakuş, 2017). Nevertheless, research that looks at both comparatively is mixed, with some arguing for descriptive geometry courses with physical media (Górska, 2005), while others find CAD to be better, or suggest working in a multimedia format while including sketching too (Marunić & Glažar, 2014).

Furthermore, another tool frequently used is creativity tests, but once again, results are looked at individually, supporting CAD (Chang et al, 2016) and sketches (Sami & Özer, 2024) for fostering creativity. Notably, Sami & Özer (2024) also suggest that figural sketches (drawing and modelling) and verbal sketches (textual expressions) influence different parts of creativity. Yet another method implemented is the assessment of designs using criteria, as Al-Mataraneh and Fethi (2017) used it to assess the negative impact of CAD tools and limited understanding of their integration on architectural design quality. This method allows them to test the workflow's effect directly on the actual end product, the design. Another study uses it to show the difference in design quality when using BIM and collaborative tools in contrast to traditional CAD software (Zaouia & Mazouz, 2024), indicating the variation present within the digital medium itself.

In conclusion, while some published research examines the strengths of each mode of designing separately, few tackle it comparatively, and even fewer consider it within the context of architectural design itself, opting to measure skills that influence the design instead. This paper will help validate some claims put forward in previous research and strengthen their position.

Research Methodology

This is quantitative research. It is comprised of two parts: the first part is a survey and the second an examination of previous design work. The target population is third to fifth-year architecture students at the University of Bahrain, to whom the survey was administered online as well as handed manually.

In the survey, students were requested to reflect on their experience in a specific design semester of their choice regarding the frequency of using design tools in each of the three design stages outlined above (conceptualisation, schematic design, and design development). For the purpose of this research, schematic design was considered to be the work produced before the mid-semester evaluation (midterm jury), while the design development was the work produced after it till the final evaluation for the course (final jury).

Moreover, the design tools inquired about are split into physical tools and digital tools, where respondents rated the frequency of their usage for the specific tool on a scale from 'Often' to 'Never' in each design stage separately. Finally, the survey inquires whether they think the usage of these physical tools enhances their design ideas, followed by an optional open-ended question on elaborating their answer (see Appendix 1). This brought the total number of questions to 33 questions, including demographic questions.

Participants were asked to attach that semester's final jury presentations, which were then analysed based on criteria to provide evidence on the actual impact of the physical or

digital methods on the final design. These criteria were developed based on the literature review and fall under four categories: site context, concept, functionality, and presentation. An unbiased team consisting of the researcher and a university instructor with experience in design rated the categories and their sub-categories on a scale of 1 to 5, from 'Poor' to 'Excellent' for a total of 16 criteria (see Appendix 2). Then, a test was conducted to check the correlation between the two values: the survey and the criteria results.

Findings and Analysis

Survey results

The survey had 18 respondents, of which 88.9% were female, and 11.1% were male (Table 01). Most of the students were in their fourth year at 72.2%, followed by third-year students at 16.7%, and fifth-year students at 11.1% (Table 02).

Table 01: Participants gender
GenderP

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Female	16	88.9	88.9	88.9
Male	2	11.1	11.1	100.0
Total	18	100.0	100.0	

Table 02: Participant university year
Year

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 3rd year	3	16.7	16.7	16.7
4th year	13	72.2	72.2	88.9
5th year	2	11.1	11.1	100.0
Total	18	100.0	100.0	

Regarding the usage of physical methods during the conceptualisation phase, 5.6% had not used them at all. The percentage of students who had used them frequently is 72.2%. In comparison, all participants used digital tools, and the percentage of frequent users was at 94.5% (Fig. 01). This indicates that most use a mix of the two methods for conceptualisation, but overall, they rely more on digital tools.

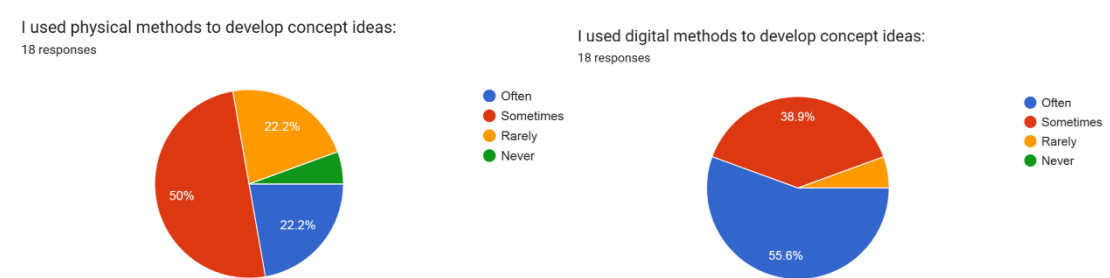


Fig. 01: Tools used in the conceptualisation stage

For the schematic design and design development stage, more detailed questions regarding each tool were asked. Some notable points include how more people use freehand sketching in the schematic vs design development stages (Fig. 02). Freehand sketching was the most frequently used physical method in designs in both stages, and although the frequency of usage drops at the design development stage, it is still used consistently by most.



Fig. 02 Use of freehand sketches in schematic design and design development stages

The other physical methods follow the same trend of lowered frequency in later stages, except for the creation of study models, where regular usage increased from 61.1% in schematic design to 72.2% in design development stage (Fig. 02).



Fig. 02: Use of study models in schematic design and design development stages

Compared to the decline in physical methods use, it has been found that students increase their usage of different digital tools in later design stages, such as a slight increase in BIM usage, which was already heavily used (Fig. 04), or frequently more usage of specialised rendering software (Fig. 05). The most frequently used digital tools on average were BIM, rendering, 2D drafting, 3D modeling, digital sketching, and analysis software, in that order.

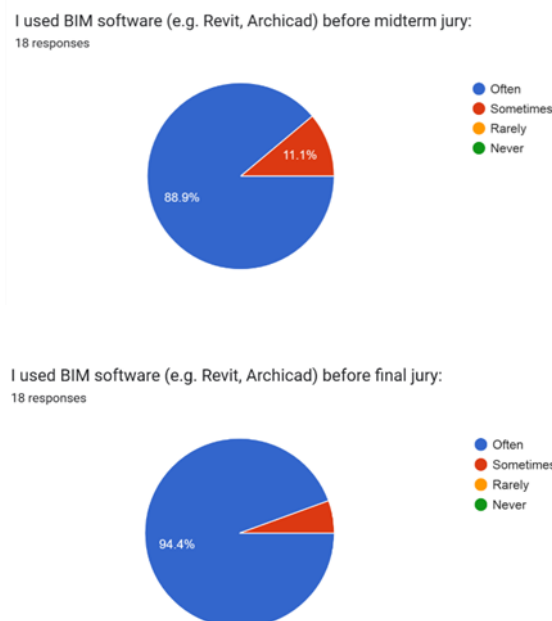
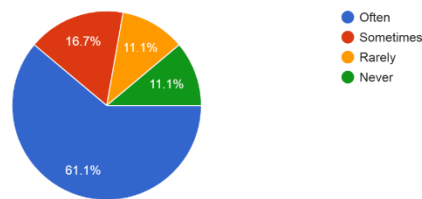


Fig. 04: Use of BIM software in schematic design and design development stages

I used rendering software (e.g. Lumion, Enscape) before midterm jury:
18 responses



I used rendering software (e.g. Lumion, Enscape) before final jury:
18 responses

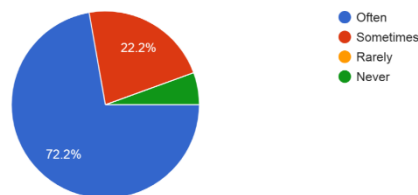
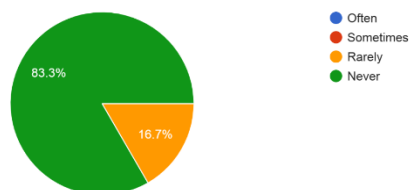


Fig. 05; Use of rendering software in schematic design and design development stages

However, it is also noted that very few students used analysis software in both stages of design (Fig. 06), indicating that they do not use digital tools to their full potential.

I used analysis software (e.g. Vasari) before midterm jury:
18 responses



I used analysis software (e.g. Vasari) before final jury:
18 responses

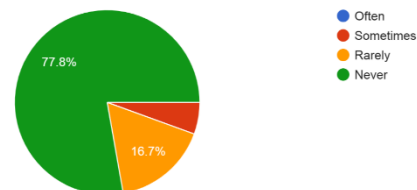


Fig. 06: Use of analysis software in schematic design and design development stages

Overall, it has been found that students' usage of physical methods is at its highest in the conceptualisation stage, decreasing in each stage on average. Meanwhile, usage of digital tools is the lowest in the schematic design and the highest at the conceptual stage. At the same time, digital methods are always used more at any stage on average (Fig. 07).

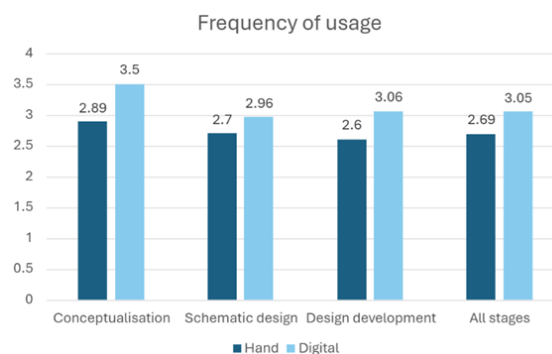


Fig. 07 Frequency of usage of methods for each design stage, on a scale of 1 to 4

Finally, participants were asked about their thoughts on whether physical media helps enhance their ideas (Fig. 08), to which 66.7% agreed, 22.2% were neutral, and 11.2% disagreed.

One student says: “Sketching out ideas for in the initial stages help with the flow of thought process and enables me to think in a streamlined manner”, showing what she values about the sketching process.

I feel my use of physical methods in the design process enhances my ideas:
18 responses

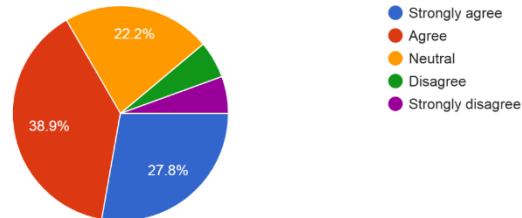


Fig. 08: Student opinions on the effect of physical methods on their ideas

Design Quality Criteria

The criteria were applied on 6 students' work from the above survey, then tested for correlation between their quality and the frequency of their usage of physical or digital design tools for each stage (Table 03, 04, 05, and 06). Due to the very small sample size, all results were not statistically significant (p-value was larger than 0.05).

Table 03: Correlation between hand or digital methods and the design quality from criteria at conceptualization

			physical_conc	digital_conc	Crit_sum
Spearman's rho	physical_conc	Correlation Coefficient	1.000	-.318	-.068
		Sig. (2-tailed)	.	.198	.899
		N	18	18	6
	digital_conc	Correlation Coefficient	-.318	1.000	-.101
		Sig. (2-tailed)	.198	.	.848
		N	18	18	6
	Crit_sum	Correlation Coefficient	-.068	-.101	1.000
		Sig. (2-tailed)	.899	.848	.
		N	6	6	6

Table 04: Correlation between hand or digital methods and the design quality from criteria at schematic design

			Mid_hand_mean	Mid_digi_mean	Crit_sum
Spearman's rho	Mid_hand_mean	Correlation Coefficient	1.000	.004	-.058
		Sig. (2-tailed)	.	.988	.913
		N	18	18	6
	Mid_digi_mean	Correlation Coefficient	.004	1.000	-.261
		Sig. (2-tailed)	.988	.	.618
		N	18	18	6
	Crit_sum	Correlation Coefficient	-.058	-.261	1.000
		Sig. (2-tailed)	.913	.618	.
		N	6	6	6

Table 05: Correlation between hand or digital methods and the design quality from criteria at design development

			Crit_sum
Spearman's rho	Final_hand_mean	Correlation Coefficient	-.116
		Sig. (2-tailed)	.827
		N	6
	Final_digi_mean	Correlation Coefficient	.091
		Sig. (2-tailed)	.864
		N	6
	Crit_sum	Correlation Coefficient	1.000
		Sig. (2-tailed)	.
		N	6

Table 06: Correlation between hand or digital methods and the design quality from criteria at overall design level

			All_hand_mean	All_digi_mean	Crit_sum
Spearman's rho	All_hand_mean	Correlation Coefficient	1.000	.054	-.058
		Sig. (2-tailed)	.	.831	.913
		N	18	18	6
	All_digi_mean	Correlation Coefficient	.054	1.000	-.058
		Sig. (2-tailed)	.831	.	.913
		N	18	18	6
	Crit_sum	Correlation Coefficient	-.058	-.058	1.000
		Sig. (2-tailed)	.913	.913	.
		N	6	6	6

Analysis and Discussion

The survey findings are validated by findings in other studies. Starting with conceptualization and sketching, Ulme and Elere (2023) found that most students in two different samples often used freehand sketching, matching this research's findings about it, where they elaborate by explaining that they also communicate their design ideas with colleagues and instructors through sketching. Ekhaese et al. (2017) also show that the majority of students use freehand sketching to present "immature ideas" (which could be ideas currently being developed for conceptualization or ideas they are working on for schematic design). The high usage of freehand sketching could owe to the fact that sketching is fast and easily communicates the idea, as mentioned by a respondent in Veisz et al. (2012): "A quick sketch on a white board or back of a piece of paper during a meeting or at a co-workers office is the absolutely fastest way to accurately convey an idea. It is also a valuable tool in explaining how something works to a client or supplier".

Ekhaese et al. (2017) noted that most rarely or never use manual drafting with a t-square, which lines up with this research's findings in all stages. This could be because the CAD drafting tools are very efficient, fast, easy to modify, and accurate, which negates the need for manual drafting. In addition, the university this current research was performed on mandates that digital drawings are used for final design presentations, which might make the students feel that manual drafting is pointless and cannot be used for presentations despite requiring a great amount of effort. Fakhry et al. (2021) show the same large preference for CAD over manual drafting in technical drawings, citing the same reasons.

As for modeling, which saw an increase throughout different design stages, it could possibly be caused by the students' need to visualise their project in the real world as they fine-tune form and structural detail. It could also be because the university requires a model submission at the end of the semester, so it could be in preparation for that. Despite this, a few students do not use study models at all. Tracing paper could be used heavily during the schematic phase due to the flexibility and ease of which details can be changed on the fly

(Heumann, 2012), and it continues seeing strong usage in design development, although to a lesser degree, likely because the design is more fixed at this point.

On the other hand, findings about digital methods also match previous research. Students' usage of digital tools is higher, indicating their preference for it, rising from reasons such as time saving, efficiency, and visual results (Fakhry et al., 2021; Al-Matarneh & Fethi, 2017; Olukoya & Kuti, 2015). Ekhaese et al. (2017) show a large number of students also using CAD software to communicate immature ideas, albeit to a lesser degree than sketching. This particular finding does not match the results of this study, where even in the conceptual stage, CAD software was more dominant. Most students used software studied at university, such as Revit or BIM tools (which is used by all students frequently), followed by 3D drafting tools like Autocad, then 3D modeling software like SketchUp which is taught in some elective courses, then finally analysis or generative software like Vasari that they would have learnt independently. The only outlier is the usage of specialised rendering software that is only taught in elective courses or learnt independently yet was the second most frequently used digital tool. This highlights the importance students place on good visuals and rendered representations of their drawings, a result that is easy to achieve with these software compared to other digital tools as well as physical ones.

As seen from the results, the majority of students find that the use of hand and physical design means enhances their ideas, and so most students used a mix between CAD and physical methods. Al-Matarneh and Fethi (2017) also explain that students feel the end product is easier to visualise when using both CAD and physical methods together. However, it is apparent that many do not use these methods even when they feel they give them better results, which could be due to the same reasons as to why students do not use manual drafting: the first being that CAD is simply superior in time efficiency, accuracy and cost-effectiveness, the time factor being especially relevant. The second reason is the university submission guidelines, which are required to be made digitally using CAD, so if the guidelines drive them to use CAD in the end, the students might be compelled to stick with using it from start to end, whereas blending CAD with physical methods would require more time and effort to balance the two.

Conclusions

This paper concludes that most people use hand methods but reduce the usage in each phase; regardless, digital tools are still used more in each phase. This is because of time, efficiency, and university guideline constraints. Hand is mostly used with tools that give more flexibility and easy exploration of ideas such as sketching and tracing paper with reduced usage, the exception being study models that see more use later. In contrast, digital is used for all things. It also leans a lot into precise tools with heavy amount of information built in and tools which produce visually pleasing results (rendering), leaving more ambiguous drawings (digital sketches) and analysis software behind with less use. Most students expressed that physical methods enhance their ideas, indicating they are not ready to leave them behind; still, they do not use them as much despite their positive opinion of it, again, due to CAD efficiency and lack of time.

It is recommended that the current research is repeated with a larger sample to corroborate the findings. It can also be expanded on by adding the buildability criteria back in. Furthermore, the researcher recommends that the hand is integrated better into design courses and its use be encouraged in order to reap its benefits. Students can also be taught about the most efficient way of integrating it into their design workflows to enable them to use this process as working professionals later on.

Limitations

Due to the time constraints, there were few participants. Moreover, the voluntary nature of the survey allowed only interested students to participate, meaning that there might be a slight bias in sampling. The criteria results were non-significant due to the small sample size, which makes detecting true effects harder (Button et al., 2013), while outliers also affect the results more heavily. Additionally, many studies included the 'buildability' or 'structural stability' as a design quality indicator. However, this criterion was not included in the present

research, as we aimed to include a larger sample of students; hence, third-year students who do not apply structure in their designs yet were included.

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Conflict of Interest: The author declares that there is no conflict of interest in conducting this research and publishing this paper

Ethical Research Practice: The research adopted standard ethical procedures. The respondents were free to participate and had no objections to performing the tasks required. They were not forced and were free to withdraw at any time.

Availability of Data: Data produced for this research is available for further scrutiny if required by any legitimate party.

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