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Which visualisation tools and why? Evaluating perceptions of student and practicing designers toward Digital Sketching

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Abstract

An ever-increasing array of design visualisation tools are available to designers. As such, design education is constantly challenged to keep up with these trends so that students are best equipped for entering industrial practice. This paper reports a study into the use of digital sketching, a relatively new digital visualisation tool. The study aims to identify thematic differences in how students and practitioners perceive digital sketching. These are given in terms of the tool's characteristics, and how these characteristics guide its application in early stages of the design process. Data on perceptions is captured using design diaries and semi-structured interviews. Results show key differences in the way that practitioners perceive the intent of visualisation. Practitioners focus on iterating towards a solution during the design process. Students are much more focused on the task of creating visualisations. This reveals an underlying contradiction in the way tools are perceived between creating visualisations to gain expertise or skill, versus creating them to advance the design process. The insights help improve our understanding of how the different characteristics of digital sketching inform its use. We reflect on how we educate students with respect to selecting and using digital sketching. We conclude with implications for education of digital sketching, as well as other emerging digital visualisation tools.

Keywords

Digital Sketching, Emerging Technologies, Visualisation, Prototyping, Design Education, Fidelity

Introduction

There is a wide array of visualisation tools available to designers in industrial and engineering design disciplines. More and more variations of sketching, 3D modelling, physical and non-physical prototyping, as well as virtual and augmented reality (VR/AR) applications are becoming commonplace (Zhang, Ranscombe, Radcliffe, & Jackson, 2019). As computing technology advances at an ever-rapid pace, so too does the capability and breadth of applications for digital visualisation tools in the design process. By extension, design educators are faced with the challenge of choosing the most appropriate technologies in which to educate students (Abouelala, Janan, & Brandt-Pomares, 2015). These be meaningful for years to come and effective in helping students create the outcomes of the future. At the same time, students also need to be educated on how the choice of tools can markedly influence the design process and its outcomes (Brisco, Whitfield, & Grierson, 2020).

Well established visualisation tools such as traditional sketching and CAD have been studied as to how their characteristics can influence designers' thinking and hence their optimal use during the design process (Lawson, 2002; J. A. Self, 2013; Tsai & Yang, 2017). From the perspective of design education these tools have also been researched with a major trend highlighting that students have a preference to use more high-tech tools that characteristically offer visualisations with greater levels of detail and realism (Ranscombe, Bissett-Johnson, Mathias, Eisenbart, & Hicks, 2020; Thurlow & Ford, 2017). In turn, the selection of higher fidelity digital visualisation tools (e.g., 3D modelling and rendering) over lower fidelity tools, such as sketching, leads to corresponding negative impacts. These include bounded ideation and an unwillingness to iterate (Robertson & Radcliffe, 2009; Thurlow & Ford, 2017; van Passel & Eggink, 2013). Conversely an indicator of more experienced designers is being adept at applying a range of tools to traverse a wide range of ideas (idea fluency) more effectively, iterating towards highly developed solutions (Crismond & Adams, 2012; J. Self, Dalke, & Evans, 2009)

Given the trend in students' preference for high-tech tools discussed above, and the unrelenting advances and sophistication in digital visualisation tools becoming available, there is a need to research the perceptions of students towards selection and use of digital visualisation tools within the design process. At the same time, given experienced designers are more adept at tool selection, there is also value in capturing their perceptions of tools to reflect against student perceptions. The visualisation tool this paper focuses on is digital sketching, an example of a relatively new/emerging visualisation tool. The specific research aim is to identify thematic differences in how students and practitioners perceive digital sketching in terms of the tool's characteristics, and how these characteristics guide its application in early stages of the design process. In doing so, we aim to provide insights on how we educate students with respect to selecting and using digital sketching and, by extension, other emerging visualisation tools. The following section gives a background to digital visualisation tools in design education and explains our approaches to characterise design tools.

Background

As a background to this study, we will first summarise the extant literature on the topic of digital visualisation tools in design education. This provides a basis for the study and the subsequent review of the different characteristics of visualisation tools.

Digital visualisation tools in Higher Education

As stated in the previous section, a body of research exists exploring the role of visualisation tools within the design process, including student use (or lack of) different tools. Traditional sketching is routinely flagged as a critical visualisation tool for designers, as a means to embody ideas as well as communicate them to others (Goldschmidt, 1991; Lawson, 2006). Speed, opportunity for reflection and reinterpretation as the designs emerge on the page are cited as key reasons for its use. Yet, research in design education shows that despite these positive characteristics, inhibition to share and communicate with sketches mean students often do not engage easily with this tool (Thurlow & Ford, 2017; van Passel & Eggink, 2013). Instead, students have a preference for more advanced digital visualisation tools that offer greater resolution and visual aesthetic (Ranscombe et al., 2020). Scholars have linked these tools to negative impact on; creativity (bounded ideation), breadth of ideas explored, and willingness to iterate possible solutions (Robertson & Radcliffe, 2009; Thurlow & Ford, 2017). Conversely

researchers have also identified a marker of experienced designers is their capacity to select different tools based on their suitability to different design activities and goals (Crismond & Adams, 2012; J. Self et al., 2009). This final point should be noted as it supports the practice of educators to refer to those in industry to outline which visualisation tools should be included in design curricula.

Among the breadth of new visualisation tools referred to in the Introduction is digital sketching. For the purpose of this paper, we define digital sketching as a visualisation tool that affords drawing (usually with pen/stylus-based input) in 2D digital design software (See example in Figure 1). Recent decrease in costs of digital sketching hardware, increased computational power, and integration of sketch input within some 3D modelling software has seen its use rise in industry and cemented its presence in design education. Recent research into digital sketching suggests it embodies a form of hybrid visualisation tool. It offers some of the complementary characteristics of traditional sketching (speed and reinterpretation) and CAD (detail and aesthetics), hence mitigating some of the issues highlighted above (Ranscombe, Zhang, Rodda, & Mathias, 2019). Thus, digital sketching is the focus of this paper as we contend it is an example of a relatively new or emerging type of digital visualisation tool. As such, we seek to inform design education's approach to incorporating this design tool in design education.

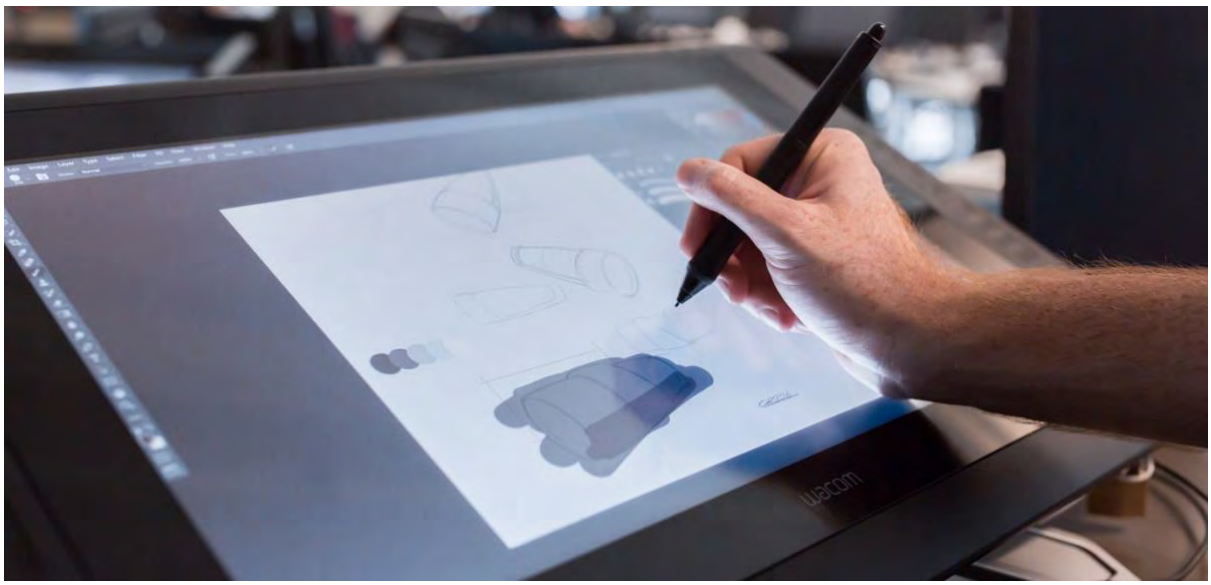


Figure 1. Example of a digital sketch created using a digital tablet and stylus (Author's own)

Characterising design tools

Extant literature on design processes (Purcell & Gero, 1998), visualisation (Pei, Campbell, & Evans, 2011; J. Self et al., 2009), prototyping (Camburn et al., 2017; Mathias, Hicks, Snider, & Ranscombe, 2018) and collaborative design (Brisco et al., 2020) offer various frameworks to study design tools and their applications by classifying their characteristic benefits and limitations. While digital sketching is the focus of our study, the purpose is to provide insights on tool use that can be generalised beyond digital sketching to the study of other emerging tools. To do so, we require a means to characterise design tools in a generalised way. The frameworks referenced above illustrate the utility of design tool characteristics as a basis to

analyse design visualisation tools in the industrial design field. Furthermore, a number of frameworks have been employed to research designers' use of tools (M. Evans & Aldoy, 2016; Jonson, 2005; Lutters, Van Houten, Bernard, Mermoz, & Schutte, 2014; Robertson & Radcliffe, 2009), setting a precedent for researching tool characteristics as a way to inform best practice. Existing frameworks to classify the use of design tools also provide different perspectives on investigating the design tool characteristics. These include both the tools' capabilities and those of the users' applying the tools. However, existing highly cited frameworks (Pei et al., 2011; J. Self et al., 2009) comprise a relatively limited number of characteristics, which may put constraints on conducting in-depth investigations of different tools. Similarly, the individual frameworks usually focus on a particular tool or perspective such as affordances of tools. Alternately they are without the context of the user's capability, limiting the applications of the framework in broader contexts.

More recently, Zhang et al. (2019) synthesised the literature to present an exhaustive framework of generalised design tool characteristics, which is used as the basis to compare even substantially different tools (sketching and CAD) (Zhang, 2020). The Design Tool Characteristics (DTC) framework combines the perspectives of both the affordances of the design tools and designers' tool-use behaviours and activities. The DTC framework also offers a more comprehensive list of universal design tool characteristics, providing a foundation to understand various design tools at different stages during the industrial design process. Moreover, the DTC framework's comprehensiveness enables comparing the design tools from a multifaceted view. This is because associations between characteristics can be captured in addition to individual characteristics if desired. Hence, for these reasons it is adopted in this study as the best means to understand perceptions in terms of design tool characteristics, and in a generalised manner (See Table 4 for a summary of the framework).

Method

The method used to evaluate student and practitioner perceptions of digital sketching in terms of the tool's characteristics is now described. Participants in this study are first outlined, then details of the diary and semi-structured interview methods adopted are explained. This is followed by an explanation of coding to highlight themes in perceptions from the two groups studied, explaining how referencing of design tool characteristics forms the basis for comparing perceptions of digital sketching.

Participants

Student perceptions were gathered as part of a visualisation course taught to postgraduate students undertaking a Masters of Design degree at Swinburne University of Technology. A total of 69 students were sampled over 2 consecutive years of delivering the same design project within the same design visualisation course (2017 and 2018). Perceptions were captured in the context of a 7-week design/visualisation project where the objective was to create concepts for a household appliance (a pod coffee machine). This project was selected as the basis for analysis as it reflects a typical design activity (i.e., ideation and concept design) in which digital sketching is used. Students were expected to use digital sketching throughout the project but had the choice to use 3D modelling software towards the end of the project.

For our practitioner sample, eleven practitioners from three engineering and design consultancies in Melbourne, Australia were interviewed during May and June 2018.

Consultancies were targeted as such practitioners would likely have worked on a wide range of products during their tenure. In-house design teams were avoided as they would likely only have experience with a certain product category. The sample of eleven participants captured a range of experience levels from junior designers to design/project managers (further details shown in Table 1).

Table 1. Details of practitioners interviewed

Participant	Experience (Years)	Company	Role
P1	>5	1	Project Leader
P2	≤5	1	Designer
P3	>5	2	Designer
P4	>5	3	Designer
P5	>5	1	Manager
P6	>5	2	Project Leader
P7	>5	1	Designer
P8	≤5	1	Designer
P9	≤5	1	Designer
P10	≤5	1	Designer
P11	>5	3	Manager

Instruments: Student diaries and practitioner interview structure

Student perceptions were collected using a diary method as used in comparable studies (Badke-Schaub & Frankenberger, 1999; M. A. Evans, Pei, Cheshire, & Graham, 2015; Pedgley, 2007). The diary method was selected on the basis that it facilitates capturing data for a large number of students at various points throughout their design process. Diary entries were recorded by students as part of a design project portfolio that students submitted at the end of the project. Diary entries were made on a standardised template throughout the project at weekly intervals over the duration of the project. They were submitted as part of their design project portfolio at the end of the course. Within each entry, students were prompted to reflect in up to 100 words on the use of digital sketching to visualise and develop or modify their ideas. Specifically, students were given the following two prompts to answer in each diary entry; “How did you find digital sketching to visualise ideas?”, and “How did you find digital sketching to develop or modify your ideas?” These prompts were designed to reflect the way in which designs are initially conceived but also developed over the course of a design project. Prior to analysis, diaries were screened for intelligibility and relevance to the study. Of the 69 students

recruited, 7 student diaries were excluded from analysis due to multiple blank or nonsensical entries. The remaining 62 diaries were transcribed and transferred to an NVivo database for coding.

Data collection for practitioners was carried out with careful consideration for intellectual property and time constraints of those involved. As a consequence, it was not possible to acquire equivalent diary entries embedded within a project portfolio from practitioners. As an alternative, a semi structured interview method was adopted. The rationale for using interviews was to capture perceptions and lived experiences of designers' use of the tool within design projects without disclosing intellectual property. Second, it facilitated further questioning and context building by the interviewer providing rich data. A controlled experiment in which all participating designers work on the same task was avoided as such an experiment would take the designers out of their natural or preferred practices. Likewise, although a standardised task would aid comparison, it would also mean key findings are potentially only relevant to the task at hand.

Each interview lasted approximately 60 mins (45mins being the shortest and 89mins being the longest). The interview followed the structure set out in Table 2. These prompts were designed to cover the same topics as students' diaries (visualisation and modification of emergent designs), while giving flexibility to pose further questions. Participants were asked to base their responses to questions on recent design projects that they felt were representative of their typical design activities.

Table 2. Semi-structured interview prompts

Prompt	Theme
What tool and representation do you prefer to visualise your ideas in the early design phase? Why?	Visualising
Are the design tools quick enough to catch up with your creative flow during the design process?	Visualising
Do you find Digital Sketching easy and effective for moving between design ideas (different solutions)?	Visualising & modifying
Is it easy to make changes to ideas using Digital Sketching?	Modifying
Do you find Digital Sketching helpful for developing details and variations of one/the same design idea?	Modifying
(Follow-up Question): Do you think it is more related to the tool itself or your expertise/skills regarding this answer?	

Primary Data Coding

The design tool characteristics framework by Zhang et al. (2019) is adopted as the basis to code diaries and interviews. Due to the different form of data collected between students (diary) and

practitioners (interview), a two-staged approach to analysis was adopted. First, a high-level coding was conducted using the same scheme to analyse both student and practitioner data sets. This formed the basis to draw out themes in students' and practitioners' perceptions. Primary coding was conducted using a scheme based on Zhang et al. (2019), but where characteristics are grouped into higher level themes (see Table 3 for definitions of each theme and Table 4 for how design tool characteristics are grouped into themes). The number of references to each code/theme was counted, and relative proportion of themes coded with respect to the total data set is given.

Secondary Coding for further analysis of practitioner data

Practitioner interviews were coded a second time using the full DTC framework (Zhang et al. 2019) describing higher-level themes in more detail in terms of specific DTCs. Table 4 sets out the secondary coding scheme outlining how specific characteristics relate to themes coded in the primary coding stage. As such the richer coding forms the basis to explain similarities and differences between students and practitioners. It also forms the basis to discuss implications for design education with respect to how the best applications of digital visualisation tools are taught in design education. Practitioner interview transcripts are coded in the same manner as in the primary coding with data is presented proportionally. This facilitates high level evaluation of similarities and differences between students and practitioners.

Table 3. Definitions used in the high-level coding scheme

High - Level Themes	Communication	Design Thinking	Representation	Time	Usability
Definition	References to the tools' capacity to communicate emergent designs. This includes communication with others but also the concept of "Dialogue with Self" (Goldschmidt, 1991), referring to the externalisation of an emergent design to support a self-reflective activity	References to designerly ways of thinking. Statements that relate to cognitive activity that typically occurs alongside visualisation activities. Includes statements that reference concepts such as problem reframing and lateral and vertical transformations to a design.	References to the resulting qualities of visualisations. This category represents the manifestation of visualisation rather than any activity (cognitive or physical) by the designer to create the visualisation.	References to the time involved in creating visualisations. This includes reference to the use of visualisation media but also the time taken to learn how to use a given media.	References to usability, and considerations associated with creating visualisation media.

Table 4. Design Tool Characteristics used to further code practitioner interviews

High Level Themes	Communication	Design Thinking	Representation	Time	Usability
Framework of Visualisation Tool Characteristics (Zhang et al., 2019)	External Communication	Lateral Transformation	Accuracy	Learning Cost	Compatibility
	Internal Communication	Problem Re-Framing	Ambiguity	Use Cost	Flexibility
		Vertical Transformation	Amount of Representation		Immediacy
			Fidelity		Mobility
			Holistic View of Objects		
			Level of Aesthetics		
			Level of Details		

Results

First, data from primary coding is presented for evaluation of thematic differences in how students and practitioners perceive digital sketching. Next, results from secondary coding of practitioner data are given to provide richer understanding of designer perceptions with respect to characteristics that guide their use of digital sketching. A discussion of the differences and explanation of findings is subsequently given in the discussion section.

Student and practitioner perceptions of digital sketching

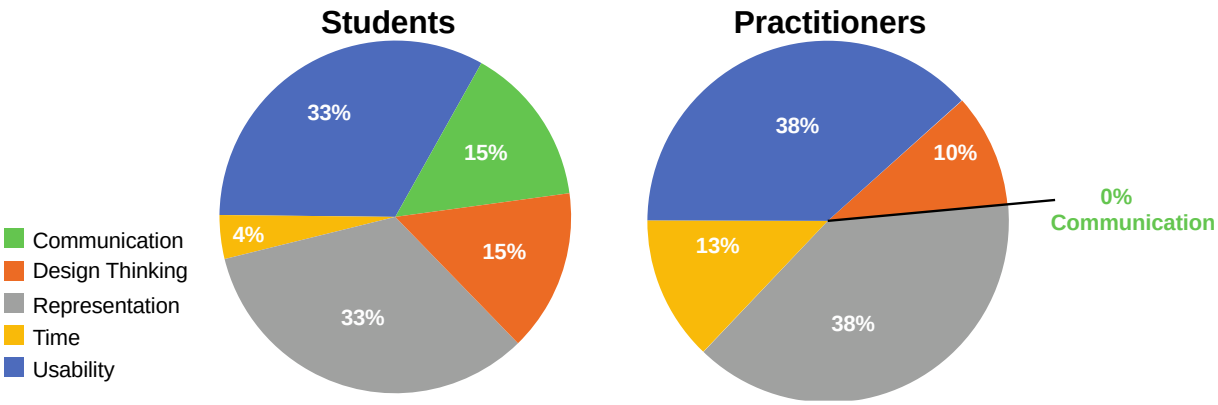


Figure 2. Overview of high level themes referenced by students and practitioners

The greatest contrast between student and practitioner perspectives is that practitioners make no reference to using visualisations to communicate (i.e. zero references under the communication theme). We contend this is partially explained by some diary entries explicitly

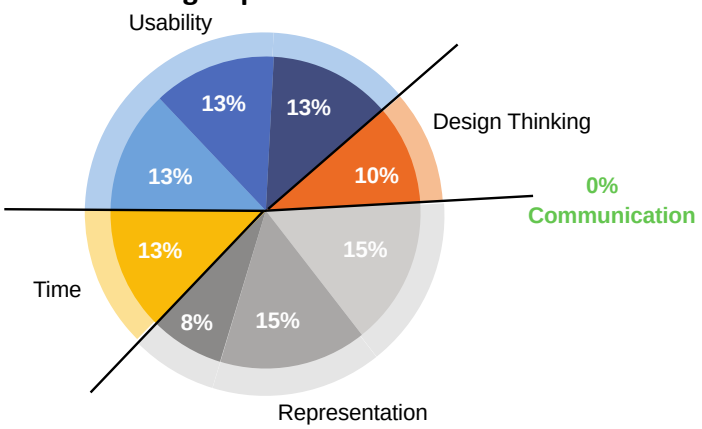
referencing the way students use their visualisations to seek feedback from teaching staff or classmates. For example, “After consulting with the tutor, the form was recreated with curved edges” and “draw them and express them in front of others” and “problem to introduce them through Maya software”. In comparison, practitioners do not explicitly describe the use of visualisations to communicate with others when developing their own ideas. Likewise (as explained in 3.1) practitioner responses that relate to visualisation with a client or external stakeholder were excluded from the comparison. It is noted that the communication category does include “dialogue with self” which would not be excluded. The lack of this kind of reference is discussed in following section.

The next biggest difference between data sets is in referencing of the time theme, 4% by Students and 11% Practitioners. While the proportion of references is relatively low, the comparative difference is almost threefold. Further discussion of this difference is given in the following section.

Evaluating the themes in student and practitioner perceptions, there is similarity in their frequent referencing of representation and usability themes. The relatively large proportion of references to the representation theme (approximately one-third of responses) is perhaps not surprising. It could be argued that the primary objective of any design visualisation is to represent potential ideas. Thus, it is expected that characteristics relating to this objective (or that describe the manifestation of visualisation) feature heavily in responses of both groups.

Finally, we note there is a small difference in the proportion of references to the design thinking theme by both student and practitioner data sets (15% and 9% respectively). As with the communication theme, it is a relatively low level of referencing by both groups. We contend this stems from digital sketching being used to “design”, and therefore its connection to design thinking is implied but not explicitly expressed.

Further coding of practitioner interviews



High Level Themes	Design Tool Characteristics
Communication	
Design Thinking	Vertical Transformation
Representation	Fidelity
	Level of Aesthetics
	Level of Detail
Time	Use Cost
Usability	Flexibility
	Compatibility
	Accesibility

Figure 3. Illustrating design tool characteristics referenced by practitioners within high level themes described in primary coding

With respect to practitioner’s views on usability, we can see this theme is described equally in terms of flexibility, accessibility and compatibility. We contend accessibility and compatibility are referring to “logistical” aspects of digital sketching meaning the access to equipment and

compatibility of visualisation with other design tools. Flexibility, however, is further from pure logistics, as it describes the flexibility to iterate or change designs. In other words, characteristics within the usability theme extend beyond pure usability of the tool, but also consider usability from the perspective of executing an iterative design process.

With respect to the representation theme, practitioners refer to fidelity of the representation and level of aesthetics in equal proportion. They describe level of detail less frequently. Associated with fidelity and level of detail is the single characteristic cited with respect to the design thinking theme, vertical transformation. When talking on the theme of representation, designers exclusively refer to the tool's capacity for iterating and developing designs in terms of adding detail. This is opposed to lateral transformation (See Table 2) which is not mentioned, defined as ideating a range of ideas. Likewise, use cost is the only time related characteristic mentioned. Learning cost (time and effort expended to learn the tool) is not mentioned, although this is likely because questions did not cover practitioners' learning experience of digital sketching. In summary, as with the range of characteristics cited in the usability theme, practitioners are motivated by characteristics that support iterative development of ideas.

Discussion

Referring to Section 4.1, the starkest differences in themes referenced by the two groups are with respect to communication and time themes. As discussed above, the difference in references to the communication theme is likely influenced by the methodology. Nevertheless, it is worth noting instances where students reference communication (seeking feedback from teaching staff or classmates) align with the external communication characteristic only. That is to say, no students made any references that point to the use of visualisation as a means of self-reflection; "dialogue with self"(Goldschmidt, 1991). This is consistent with practitioner data where this theme also did not arise. It is possible that such a view of sketching/visualisation is very theoretical, and hence not something that either students or practitioners would explicitly state.

Aside from communication, we contend referencing the time theme is most interesting in terms of differences in perceptions. References by practitioners to the time theme are largely associated with time investment to iterate and develop ideas towards a final product or concept. Moreover, this theme for practitioners is embodied by the use cost characteristic which is closely associated with Fidelity. In other words, designers are concerned with time from the perspective of developing and detailing designs. For example: "You can just do that digitally over the top, or save up copies, or even have different layers to turn on and off in Digital Sketching. So, it's much faster to do iterative work or refinement work [in Digital Sketching]" and, "once I've got a more fleshed out idea, I move into digital sketching for quicker generation of ideas".

In contrast, student references to the time theme do not include such association with iteration, development or design thinking. Rather, students are either focused on time to complete the assignment or time associated with interacting with the tool. For example, "I wasn't very fluent before and after repeating the same task again and again. I got faster, for example, using paths on PS [Photoshop] to create lines or selections." and, "When working on the concepts, everything takes such a long time because I focus on doing it properly."

The way practitioners view time is a necessary compromise in iterative development, as explained by positive and negative references to Use Cost and Fidelity. For students, time is simply the time taken to achieve a seemingly fixed outcome. It is not seen as intrinsic to the design process. This difference in perceiving time characteristics concurs with research on the skills of novice versus expert designers. Expert designers put emphasis on iterating quickly and frequently, while novice designers are solution focused, iterating less frequently within a solution (Smith & Leong, 1998; Wynn & Eckert, 2017).

Perceptions with respect to usability are somewhat aligned. For students, they relate to ease or difficulty to use software and hardware. For example, "After practicing using a Photoshop [sketching] tools, my skill with Photoshop is getting better and more comfortable which makes my work tidier." This is viewed as being focused on the creation of representations. Looking at the design tool characteristics that make up practitioners' view on usability, we see designer's references to compatibility and accessibility are more around the logistics of the design process. Designers' referencing of flexibility is however somewhat different to the themes described by students. Flexibility references refer to usability with respect to changing/modifying and developing designs. So, similar to the difference in perceptions regarding time, practitioners' perceptions of using the tool are related to the development of an emergent design or pursuing the design process.

Design tool characteristics coded within the representation theme again illustrate the way practitioners connect visualisations to iterative design process. For example, Fidelity is interesting as a characteristic described alongside time invested (use cost) to create visualisations. Likewise, level of detail is closely associated with the flexibility and vertical transformation. References to level of aesthetic align more closely to the student perspective of representing ideas. Finally, concerning the design thinking theme referenced by both groups, we contend there are relatively few references to design thinking as this is inherent within the subject matter. In other words, the use of visualisation tools to propose and iterate toward a solution is given and thus not explicitly mentioned.

Limitations

As discussed in the methods section, a limitation to the comparisons drawn between student and practitioner perceptions arises from the two forms of data collected, diaries versus semi-structured interview. While the full DTC framework is used to analyse practitioner data in the secondary analysis, this granularity was not achieved with student diary entries. As such it was not possible to draw equally deep insights in student perceptions to reflect against those of the practitioners. Hence, while we give discussion and explanation of practitioner views, it is not possible to further reflect on student views in the same manner. Although this is a limitation to the comparison of perceptions, the goal of the study is in essence to learn from the way practitioners approach visualisation, which has been achieved through the richer secondary analysis of practitioner data. Similarly, a further limitation stems from the methods selected. Opting for a method that allows designers to reflect means insights are drawn from different design projects. Each likely have different design considerations but also scope or length. As such direct comparison of data is not possible leading to our findings being limited to themes. As stated in the methods the intention of the study is explorative and to identify such themes. Further research would ideally create a more controlled experiment where variables such as designers' experience/seniority, education in visualization tools and types of design task can be

controlled creating greater comparability within the designer group as well as between students and designers.

The final limitation noted reflects the use of student participants from a single institution. Extending the study to include students from other institutions experiencing different visualisation courses would help to validate the data presented in this paper. Likewise, a broader set of practitioners from different countries, and including a mix of in-house designers, as well as consultants, would further validate practitioner perceptions.

Implications for design education

Educating students in visualisation inherently focuses on mastery of skills, i.e. accurately and fluently sketching ideas, or learning CAD software. Thus, it is not surprising that students emphasise the representation theme. The quality of representation is often the benchmark of how well they have mastered skills and hence closely related to final grades. Time taken is considered less. Moreover, we contend some students may place great importance on spending a lot of time to gain greater mastery and higher grades. In comparison for professional designers, findings show an emphasis on creating iterative designs in the most time effective manner. Thus, there is a major difference, even contradiction in the way tool use is perceived.

The key implication from differences observed is, how to teach skills in a manner that better connects the skill with designerly thinking and iteration? While 100% simulating the conditions in industry is impossible, we contend that greater emphasis on teaching students about tool qualities and tool selection, and how they influence design process and outcomes is required. At the very least by understanding characteristics of tools and comparing possible tools available, students might think beyond the skill and deliverable, and gain a sense of perspective about how the skill fits within the overall design process. Typically, course structures in higher education dictate that skills are often taught within a single unit with the intention that this knowledge is applied within projects. One recommendation is that projects may better integrate visualisation skills by also including teaching choice of tools and their relative pros and cons. We contend this would better contextualise the tool and in turn stimulate a greater consideration of purpose beyond creating the visualisation itself. Specifically, it could be worthwhile to apply a newly learned skill in projects of differing timeline and with substantially different deliverables. For example, using digital sketching to quickly create a concept versus using digital sketching in conjunction with other tools in an iterative manner over a longer project. These findings support recent recommendations in Brisco et al. (2020). While their study focuses on the use of digital tools to support collaboration, it provides a very current view that aligns in highlighting the value in educating students on the impact of tools and technology on the process of design.

Conclusions

An ever-increasing array of design tools are available to designers. As a consequence, design education is regularly challenged to keep up with trends by educating students in the use of design tools to ensure their employability in the design industry. This paper reports a study into the use of digital sketching, a relatively new digital visualisation tool. Specifically, it investigates thematic differences in the way students and practitioners perceive digital sketching between practicing designers and student designers. The overall goal being to improve our

understanding of how the different characteristics of digital sketching inform its use. In doing so we reflect on how we educate students in selecting and using digital sketching along with other emerging visualisation tools.

Results exposed how practitioners perceive/reflect on the intent of visualisation with respect to advancing the design while students are much more focused on the task of creating visualisation. This reveals a contradiction in the way tools are perceived between creating visualisations to gain expertise or skill, versus creating them to advance the design process. As such we conclude that there is a need to reconsider the way visualisation skills are delivered. Visualisation is a skill that is best learnt through practice. However, contextualising the skill within the design process to understand how different characteristics of visualisation tools (such as fidelity and time invested) influence design outcomes is needed. As such, further research intends to focus on ways to balance necessary skill learning and development while also stimulating understanding of the way tools influence process and outcome. A second area of interest is to conduct similar studies in other new and emerging visualisation platforms such as the integration of augmented reality (AR) and virtual reality (VR) in visualising designs.

References

Abouelala, M., Janan, M. T., & Brandt-Pomares, P. (2015). Methodology of selecting CAM software package for education based on a questionnaire. International Journal of Mechanical Engineering Education, 43(2), 77-93.

Badke-Schaub, P., & Frankenberger, E. (1999). Analysis of design projects. Design Studies, 20(5), 465-480.

Brisco, R., Whitfield, R., & Grierson, H. (2020). A novel systematic method to evaluate computer-supported collaborative design technologies. Research in Engineering Design, 31(1), 53-81.

Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., . . . Wood, K. (2017). Design prototyping methods: state of the art in strategies, techniques, and guidelines. Design Science, 3.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. Journal of Engineering Education, 101(4), 738-797.

Evans, M., & Aldoy, N. (2016). Digital design sketching using the tablet PC. The Design Journal, 19(5), 763-787.

Evans, M. A., Pei, E., Cheshire, D., & Graham, I. J. (2015). Digital sketching and haptic sketch modelling during product design and development. doi:https://doi.org/10.1504/ijpd.2015.069323

Goldschmidt, G. (1991). The dialectics of sketching. Creativity research journal, 4(2), 123-143. doi:https://doi.org/10.1080/10400419109534381

Jonson, B. (2005). Design ideation: the conceptual sketch in the digital age. Design Studies, 26(6), 613-624.

Lawson, B. (2002). CAD and creativity: does the computer really help? Leonardo, 35(3), 327-331. doi:https://doi.org/10.1162/002409402760105361

Lawson, B. (2006). How designers think : The design process demystified. Oxford: Architectural Press.

Lutters, E., Van Houten, F. J., Bernard, A., Mermoz, E., & Schutte, C. S. (2014). Tools and techniques for product design. CIRP Annals, 63(2), 607-630.

Mathias, D., Hicks, B., Snider, C., & Ranscombe, C. (2018). CHARACTERISING THE AFFORDANCES AND LIMITATIONS OF COMMON PROTOTYPING TECHNIQUES TO SUPPORT THE EARLY STAGES OF PRODUCT DEVELOPMENT. Paper presented at the DS92: Proceedings of the DESIGN 2018 15th International Design Conference.

Pedgley, O. (2007). Capturing and analysing own design activity. Design Studies, 28(5), 463-483. doi:https://doi.org/10.1016/j.destud.2007.02.004

Pei, E., Campbell, I., & Evans, M. (2011). A taxonomic classification of visual design representations used by industrial designers and engineering designers. The Design Journal, 14(1), 64-91.

Purcell, A., & Gero, J. S. (1998). Drawings and the design process: A review of protocol studies in design and other disciplines and related research in cognitive psychology. Design Studies, 19(4), 389-430. doi:https://doi.org/10.1016/s0142-694x(98)00015-5

Ranscombe, C., Bissett-Johnson, K., Mathias, D., Eisenbart, B., & Hicks, B. (2020). Designing with LEGO: exploring low fidelity visualization as a trigger for student behavior change toward idea fluency. International Journal of Technology and Design Education, 30(2), 367-388.

Ranscombe, C., Zhang, W., Rodda, J., & Mathias, D. (2019). Digital Sketch Modelling: Proposing a Hybrid Visualisation Tool Combining Affordances of Sketching and CAD. Paper presented at the Proceedings of the Design Society: International Conference on Engineering Design.

Robertson, B., & Radcliffe, D. (2009). Impact of CAD tools on creative problem solving in engineering design. Computer-Aided Design, 41(3), 136-146. Retrieved from http://ac.els-cdn.com/S0010448508001334/1-s2.0-S0010448508001334-main.pdf?_tid=5ff78cf6-23ac-11e5-8a18-00000aacb35f&acdnat=1436166075_9dc812d1b0ed43b7f45b2238df0fb95a

Self, J., Dalke, H., & Evans, M. (2009). Industrial Design Tools and Design Practice: An approach for understanding relationships between design tools and practice.

Self, J. A. (2013). CAD Tools and Creative Design, Grounds for Divorce or Match Made in Heaven? CAD/CAM Review, 19(2), 36-43.

Smith, R. P., & Leong, A. (1998). An observational study of design team process: A comparison of student and professional engineers.

Thurlow, L., & Ford, P. B. (2017). Where have all the ideas gone? An anatomy of sketch inhibition among student designers.

Tsai, G., & Yang, M. C. (2017). How It Is Made Matters: Distinguishing Traits of Designs Created by Sketches, Prototypes, and CAD. Paper presented at the ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.

van Passel, P., & Eggink, W. (2013). Exploring the influence of self-confidence in product sketching. Paper presented at the 15th International Conference on Engineering and Product Design Education: Design Education-Growing our Future.

Wynn, D. C., & Eckert, C. M. (2017). Perspectives on iteration in design and development. Research in Engineering Design, 28(2), 153-184.

Zhang, W. (2020). An Investigation into the Use of Digital Sketching during the Early-Middle Design Phases in Industrial Design Practice. (Doctorate). Swinburne University of Technology, Melbourne.

Zhang, W., Ranscombe, C., Radcliffe, D., & Jackson, S. (2019). Creation of a framework of design tool characteristics to support evaluation and selection of visualisation tools. Paper

presented at the 22nd International Conference on Engineering Design (ICED), Delft, Netherlands.