Is pen-to-paper the buggy whip of design? Assessing the use of ai tools for design sketching

Alexander "Freddie" Holliman
University of Strathclyde, United Kingdom

Ross Brisco
University of Strathclyde, United Kingdom

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Is pen-to-paper the buggy whip of design? Assessing the use of AI tools for design sketching

Alexander "Freddie" Holliman*, Dr Ross Brisco

Department of Design, Manufacturing and Engineering Management (DMEM), University of Strathclyde, UK

*Corresponding e-mail: alexander.holliman@strath.ac.uk

Abstract: Sketching is quick and effective, however with the advent of generative AI, do the current generation of novice designers have an alternative? This paper compares the use of sketching and text-to-image generative AI tools to produce initial concept images ("sketches") by novice designers. This will identify the viability and potential adoption of AI as a replacement, and gauge the adoption willingness of novice designers, replacing sketching. This study compares conventional sketching and AI image generation using first year product design students to record brainstormed initial concepts using both sketching and generative AI tools, this study compares various attributes of both, including ability to represent designer's intentions. The findings of this study suggest that at present, novice designers continue to prefer conventional sketching with 75% believing that it is more accurate to designers' intentions and 59.62% believing that it is easier to use.

Keywords: Product Design; Design Sketching; AI; Generative AI

1. Introduction

In design, sketching is used to create representations of designer's mental models (Eris, Martelaro, & Badke-Schaub, 2014) and contributes to the design process (Ferguson, 1994), being used across a variety of activities, from user journey mapping and storyboarding, to initial concept generation, where it is used both horizontally (producing different concepts) and vertically (developing previously recorded concepts) (Nikolić, Škec, Martinec, & Horvat, 2019). Sketching is the de facto non-textual approach to record ideas and is an essential communication tool (Fish & Scrivener, 1990).

Computational systems can contribute towards creative processes (Sosa & Gero, 2016). AI tools are no exception, with various agencies defined to establish possible use cases (Guo, Xiao, Wang, & Ji, 2023). The recent increase in popularity and availability of these AI models is due to the creation of new learning techniques that reduces their training time and consequently their development cost. Within the industrial design industry, AI tools are typically

used to automate design tasks, aid in rapid prototyping, and for personalization (Fan & Jiang, 2024). This is mirrored within the graphic design industry, with AI tools being used towards the later end of the process for more functional stages (Meron, 2022) such as the creation of page layouts. Some additional use cases of AI tools have been tested, including preliminary studies have examined whether AI tools can be used to help (or hinder) divergent and convergent thinking within a design process (Simeone, Mantelli, & Adamo, 2022); and the creation of specific AI tools use in sketching, i.e. Cao et al. (2019). Both of which require a higher degree of technical skill to use and are not widely available to the public. Additionally, Wang et al. (2021) provide a comprehensive breakdown of additional potential uses in AI within product development.

From a high-level perspective, like most tools, AI tools receive and input, which it operates on, producing an output. Of the various AI tool input-output combinations, two of the most common are text-to-text (T2T) and text-to-image (T2I), which provide the foundation for the majority of publicly available AI tools. T2T tools, like the widely known ChatGPT, are based on Natural Language Processing, a method allowing machines to understand human language. These large language models are used to predict the next best word based on the prompt. They have been used in various creative ways including fashion (Jain, Modi, Jikadra, & Chachra, 2019), custom map creation (Dunkel, Burghardt, & Gugulica, 2024), as was well as being used to create visual media, such as to program other image creation and T2I tools (Lu, Guo, Dou, Dai, & Wang, 2023).

Text-to-image (T2I) generative AI tools are typically developed from one of two technologies. Many utilize machine learning techniques such as Contrastive Language–Image Pretraining (CLIP), that are used to train models on sets of image text pairs. Others use Generative Adversarial Networks (GANs) which create new images from a combination of random noise based and a set of training images. These tools have been used in various contexts, from tourism (Miao & Yang, 2023), to being integrated into craft education (Vartiainen & Tedre, 2023). There are many creative applications for T2I for use in a product design context, with various paradigms that consider the inclusion of AI within the design process. This includes the "augmented designer" (Thoring, Huettemann, & Mueller, 2023), and those presented in the AI-Human Teaming Matrix (McComb, Boatwright, & Cagan, 2023), which has four relationship types based on area of focus (process or problem), and mode (reactive or active): AI-as-tool (problem focus, reactive mode), AI-as-partner (problem focus, proactive mode), AI-as-Analysis (process focus, reactive mode), and AI-as-Guide (process focus, proactive mode). Considering the core product design task of concept generation, which is generally a problem-focused task, then AI tools can be used as a tool or partner, based on the AI-Human Teaming Matrix.

An example of its use within this context, where T2I AI tools are used to outsource concept generation, studies, shown in studies such as Brisco et al (2023), several limitations and barriers its use, and its replacement of designers for this task have been identified. Whereas when used to contribute towards solving a problem (rather than total replacement of the designer) it has proven to be more successful. This is shown in several studies, where

Midjourney has been examined as a tool to create stimuli for concept generation, through moodboard images (Mikkonen, 2023), and has with its use to supplement brainstorming activities has been shown to be more effective than brainstorming alone (Shen, Chen, Hua, & Ye, 2023).

Being such a novel technology, there are currently numerous other barriers to the use of AI in a product design context, including a lack of expertise in their use and lack of best practice guidance (Müller, Roth, & Kreimeyer, 2023). Additional challenges faced by designers when using AI tools include the need to enhance interactivity and improve the efficiency of communication (Gmeiner, Yang, Yao, Holstein, & Martelaro, 2023) which contribute to the expectation that AI design tools will perform worse than their human counterparts (Chong & Yang, 2023). Although in time, all these issues may be addressed, they currently have significance and should be acknowledged when considering the use of AI in product design. Although outside the scope of this study, there are also several risks in the use of text-to-image generative AI, which Bird et al (2023) categorise as being either risks of discrimination and exclusion, risks of misuse, or risks of misinformation and disinformation. Although the use case that is the subject of this study can generally be considered innocuous, such risks are worth noting.

Regardless of whether the understandability of a sketch is linked to its quality (Letting, Krishnakumar, Johnson, Soria Zurita, & Menold, 2023; Macomber & Yang, 2011), sketching is a skill that requires an investment of time to develop and practice. Could the adoption of AI tools alleviate the need for this investment, empowering designers to be more productive (Torkkeli & Tuominen, 2002) and more creative (McComb et al., 2023)? A key recommendation from a study by Zhang et al (2023) found that T2I generative AI tools were best integrated in the early stages of concept development, therefore this study considers whether T2I generative AI tools can provide an alternative to pen-to-paper sketching as a tool to visualize concepts (Guo et al., 2023) in representing the ideas conceived by designers in that early stage of concept development.

1.1 Research questions

This study will address the following research questions:

- RQ1: *"How well can publicly available text-to-image generative AI tools perform as a replacement to conventional sketching for recording novel concepts in the concept generation phase of the product design process?"*

- RQ2: *"How willing are designers to adopt publicly available text-to-image generative AI tools perform as a replacement to conventional sketching for recording novel concepts in the concept generation phase of the product design process?"*

2. Methodology

This study adopts a process-oriented perspective (rather than content-oriented) (Dorst & Dijkhuis, 1995) considering the use of text-to-image generative AI tools as a replacement for

conventional pen-to-paper sketching. This study engaged with groups of first year students studying product design (or related subjects), who are working in teams towards a design project. These participants were aged between 18 and 20, the majority of whom are from the UK. Participants were provided with instructions and recorded their own results in a Microsoft Form sheet. First year design students were selected as they receive initial training in sketching skills and will have produced a product design specification document (PDS) (Pugh, 1991) to capture all the needs of the product and the customer for their project. These designer groups were instructed to collectively identify the top 5 requirements from the PDS were (i.e. weight, size, usability, etc.), while conducting the remaining activities independently.

The participants are presented with two design activities, shown in Figure 1. In both activities, the participants were instructed to create three new initial concepts to address the top 5 requirements of their PDS, as part of the concept generation phase of their design process. The participants were then required to record their ideas using one of two methods. In Activity 1 these concepts were recorded using conventional pen-to-paper sketching, while in Activity 2, the students wrote a text prompt for the T2I generative AI tool "Bing Chat" (powered by the DALL-E AI) to create an image of their concept. Alternative free-to-use T2I generative tools were considered and tested but were disregarded due to their lengthy processing times at the time of the experiment. Participants were instructed to make a digital record of their ideas, photographing their sketches and saving copies of the AI-generated images. In addition, the total duration of each activity is timed and recorded by the participant. After each activity, the participants were asked to reflect on the performance of the activity, asking them to evaluate each of their concepts on a 5-point scale on:

- How effective their images were at representing your intended concept? (1 being ineffective; 5 being an exact representation).
- How easy was it to create the image? (1 being very bad; 5 being very good).

After the completion of both activities, the participants were asked reflective questions on the activities, indicating which activity:

- they preferred,

- they considered easier to use, and

- they considered to produce images that most closely represented their intended concept.
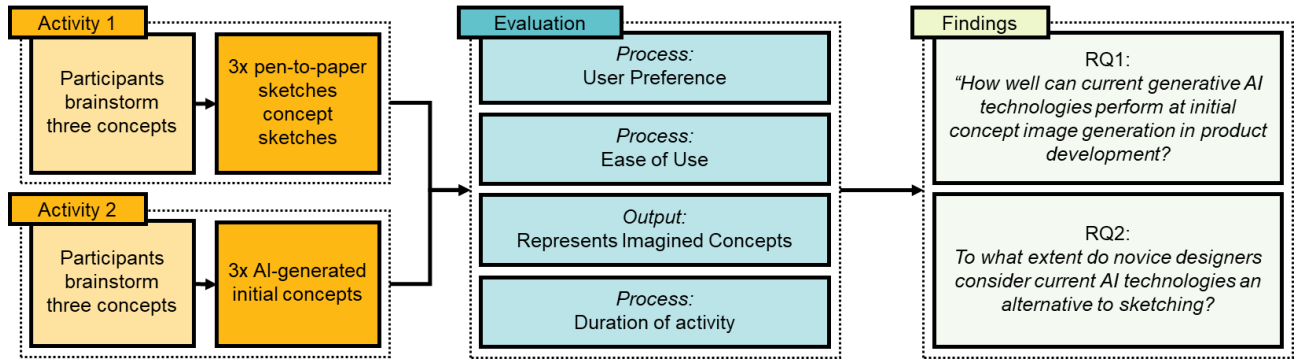
Figure 1   Research Methodology

An example of the conventional sketches and AI generated images produced by participants are shown in Figure 2. By conducting these activities, the research questions can be answered by assessing the quality and usability of T2I generative AI tools for concept image creation when compared to conventional sketches, determine the duration of each task and gauge the ease of use of each approach.

Figure 2   A Thumbnail sketch of "Wood and glass study space with sliding doors and curved roof" [Left]; and AI-generated image using prompt "Outdoor study space made of wood and glass made to seat at least 4 students" using Microsoft Bing Chat powered by DALL-E 3 [Right] by Participant 16.

3. Findings & Discussion

3.1 Findings & Discussion introduction

The results and analysis of this study are presented concurrently and will consider the participant cohort in its entirety, as well as examining specific sub-groups. The groups include those who have prior experience with text-to-image generative AI tools, as well as those with previous training in art or sketching. A cohort of 52 first year design students studying various product design-related degrees were recruited in this study. 24 participants (46.4%)

had received some form of sketching training during their time in school, in subjects like art, graphic communication or even product design, shown in Figure 3. 8 participants (15.38%) had some experience of T2T generative AI tools, while 15 (28.8%) had some experience of T2I generative AI tools, also shown in Figure 3.
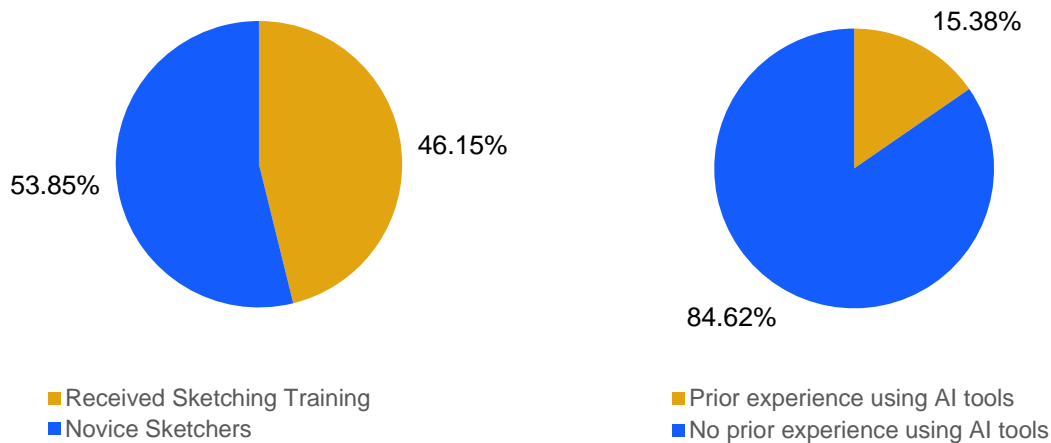

Figure 3   Breakdown of Participants with Prior Sketching Training Experience [Left]; Breakdown of Participants with Prior AI Tool Use Experience [Right]

3.2 Representing intended image

In the evaluation task after each activity, the participants gave their conventional sketches an average rating of 3.24 and their AI-generated images an average rating of 3.23, yet in the post-experiment evaluation, 39 participants (75%) participants identified conventional sketching as being more accurate at representing their intended design, shown in Figure 4. It is doubtful that the cohort would intuitively detect this 0.01 difference of evaluation, which therefore presents the question of why?

Further emphasis on sketching's accuracy can be seen when considering that of the 24 trained sketchers in the cohort, 83.33% (20) believed that conventional sketching was more effective. Whereas, of the 27 novice sketchers, 66.67% (18) held the same belief. Most significant observation for this issue are the results of the sub-group of participants who had neither sketching, nor AI experience; 84.62% (11) of whom believed that sketching produced images that more closely resembled their intentions, indicating a greater efficacy for sketching across each subgroup of the participant cohort.
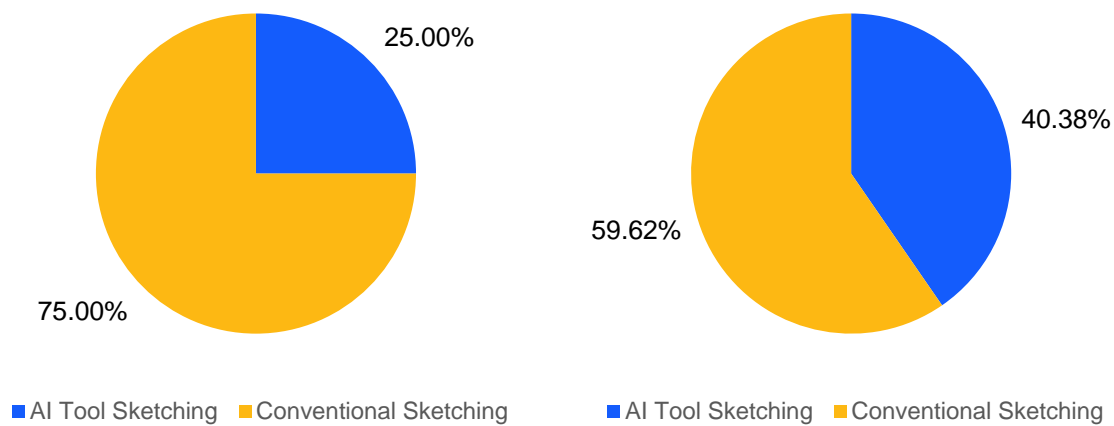
Figure 4 Participant Evaluation of Concept Image Creation Process Output Representing Participant Intentions [Left]; Participant Evaluation of Process Ease of Use [Right]

3.3 Process ease of use

59.62% (31) of participants considered conventional sketching to be easier to use than T2I generative AI, shown in the right of Figure 4. Contrary to what could reasonably be assumed, a slightly greater percentage of novice designers found sketching easier to use than AI tool use (62.96%, 17 of 28) in comparison to those with prior sketching training (58.33%, 14 of 24). The possible reason for this may be with a higher degree of skill comes with it a more critical eye of your own work, and that personal satisfaction of one's output might influence an ease-of-use judgement.

In comments reflecting on which process is easier to use, those participants that favored conventional sketching held similar attitudes to that of their rationale for why it was easier to use, with comments such as: *"Getting the AI tool to generate something relevant takes practice and partly luck"* [Participant 45]. The technical barrier combined with the challenge to produce an image as intended was also a notable reason, with several participants citing some variation on: *"AI was confusing and difficult to set up, didn't always understand what I was trying to describe"* [Participant 24].

Those that consider AI tools easier to use stated that the perceived lack of skill required as an advantage: "Doesn't involve skill" [Participant 17] and *"It's incredibly simple and it doesn't take any skill to use."* [Participant 35]. Another advantage identified by participants is the reduced time needed to produce images of higher fidelity: *"Creates more in depth photos a lot faster"* [Participant 43] and *"Less time consuming for a more detailed imagine"* [Participant 48]. Additionally, one participant considered AI tool use to be more enjoyable to use, describing their use as *"Fun and quick to input ideas that can then be built upon."* [Participant 39].

3.4 Process preference for use

67.31% (35) of participants indicated a preference for conventional sketching, with 70.83% (17) of trained sketchers and 62.96% (17) of novice sketchers Figure 5. This is intuitive as it indicates that those who have training in a skill are more likely to prefer it. Of those with AI experience, the preference remains with sketching (53.33%, 8 of 15), however the significance of this is somewhat less. This suggests a similar standpoint, that familiarity with something increases one's preference for it. However, as only 28.8% of participants had previous AI tool use experience, many of whom also had prior sketching experience (5 of the 15 with prior AI tool use experience), there may be some influence over this finding.
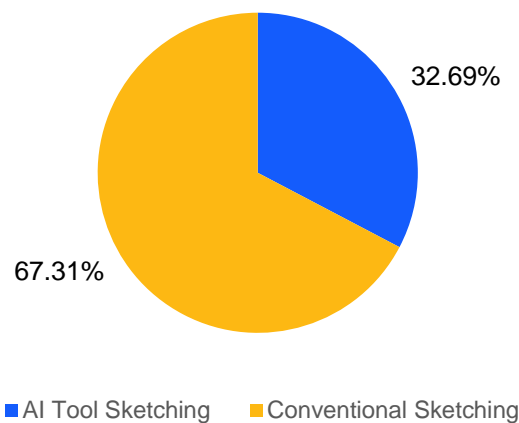

Figure 5   Designer Concept Image Creation Process Preference

Considering the reflections made by the participants, those that preferred conventional sketching, many commented on not needing to formulate ideas into words, with comments such as: *"I can just get my ideas down without having to put them into words. Using descriptive language is a challenge of mine."* [Participant 10] and *"…you can get a visual representation of your thoughts without having to describe them with words."* [Participant 28]. Similarly, many participants commented on the accuracy of the images produced, stating that sketching allowed them to produce images of concepts as they imagine them (*"I can create my exact vision without the difficulty of having to put it into words"* [Participant 47] and *"Easier to get results of exactly what you mean because you know in your own head."* [Participant 48]).

Those participants that considered AI tools as easier to use, cited the degree of detail included in generated images as a key benefit ("Easier to demonstrate ideas in detail quickly, although sketching was slightly quicker the images are very vague." [Participant 15] and "Ai sketching allows for greater detail in the concepts you create." [Participant 18]). Additionally, participants discussed the creative advantages offered by AI tool use, incorporating its use within the creative process: "…it sparked new ideas in my head, I can then use that to improve my sketches." [Participant 50], and "I feel it will give good ideas for me to further develop and means you have something to go of." [Participant 52].

Notably, 34.6% (18) of participants considered one approach to be easier to use, yet not preferable, with 7 preferring AI too sketching but finding it harder to use, and 11 preferring conventional sketching but finding it harder to use. Those participants preferring AI, their reasoning included *"It helps provide wider ideas which I can use to aid my own personal sketching"* while also stating that conventional sketching was *"Just much less 'hassle'"* [Participant 11]. Alternatively, those participants that preferred conventional sketching, but found AI tools easier to use stated reasons such as: *"Easier to get results of exactly what you mean because you know in your own head."* for sketching, and *"Less time consuming for a more detailed imagine* [sic]*"* [Participant 48].

3.5 Task duration

A breakdown of the activity completion times is included in Table 1. Participants took an average of 12:20 minutes to complete the conventional sketching task, and 13:52 minutes to complete the AI sketching task. Those with prior sketching or art training had a reduced average completion time of 9:38 minutes, while remaining consistent with average completion time for the AI sketching task (13:24 minutes). In contrast, those participants with prior experience using T2I and T2T generative AI tools had an average completion time of 13:16 minutes, which is significantly slower than those participants with sketching experience. This suggests that experience with text-driven generative AI tools does not have the same time saving quality.

Table 1   Activity Completion Times

Activity	Whole Cohort		Sketching Experience		AI Experience	
	Mean	Median	Mean	Median	Mean	Median
Conventional Sketching	12m20s	10m	12m	10m	9m56s	8m
AI Sketching	13m52s	15m	13m30s	13m	13m16s	10m

3.6 Answering the research questions

Research Question 1

This study has shown that conventional sketching produces images that more closely resemble the designers' intentions than T2I generative AI tools. Similarly, the participants of this study have indicated that conventional sketching is easier to use than T2I generative AI tools. Therefore, the currently publicly available T2I generative AI tools are not suitable replacements for conventional sketching when recording novel concepts in the concept generation phase of the product design process.

Research Question 2

This study has also shown that designers most designers prefer conventional sketching to T2I generative AI tool use when recording novel concepts in the concept generation phase of the design process. Unsurprisingly, this study has shown that this preference increases in lockstep with an increase in sketching experience. This indicates a lack of willingness to adopt to T2I generative AI tools in the recording of novel concepts during the concept generation phase of the product design process.

3.5 Study limitations

This initial exploratory study has a number of limitations that should be addressed in future work. The participants of this study were given a minimum of four hours of fundamental design sketching tuition and the opportunity to practice prior to participating in this study. They did not receive such tuition for writing text prompts, something that has been shown to be as skill in of itself (Kim, Ko, Kwon, & Lee, 2023). As discussed by some participants in their reflections, the learning curve to the use of natural language text prompts for T2I technologies is steep and therefore a broader study should be conducted incorporating participants with a range of experience levels for both sketching and AI tool use, with basic tuition offered to participants to eliminate this issue for the novel AI tool users.

This study compares pen-to-paper sketching to generative AI image creation and therefore does not consider digital sketching using tablets, etc. Although clearly closer in usecase to conventional sketching, comparisons between each approach should be made as there are intrinsic features and aspects of each approach which should be compared.

In a similar vein, this study uses one T2I generative AI tool (Bing Chat powered by DALL-E 3). Therefore, more tools should be included in future studies to explore the specific functionalities, capabilities, etc. of each tool. This will also provide a broader and deeper perspective on the current T2I generative AI tool environment, from which more robust assumptions can be made.

4. Conclusion

This study considers the replacement of pen-to-paper sketching with text-to-image generative AI to visualise designers' ideas within the design process. It must be acknowledged that the images generated via T2IAI tools will have greater visual fidelity than the thumbnails drawn by a novice designer, like those shown in Figure 2. This paper considers other critical considerations on the two processes: the speed of image creation, and the capture and representation of the designer's intentions. Both activities were evaluated against their ease of use, their ability to represent the designers' intentions and designers' preferences.

Considering the composition of the participants, and given these test parameters, this study has shown that when recording novel concepts as part of a concept generation process, sketching is generally the more suitable approach. Sketching has a faster average task com-

pletion time, produces more accurate images even by those with no experience, and is generally considered to be easier to use. For user preference, those that favour sketching link this preference to the direct nature of noting concepts, without the need for "translation" into another form, which links to their desire for accuracy to an intended idea. In contrast, AI tool sketching was preferred for the visual fidelity of AI generated images and its potential use as a catalyst for further concept development, which itself should be an area of further study. There is greater value to sketching which is untapped when adopting T2I generative AI. Designers use sketching in the concept generation phase to aid in the development of their ideas (Goldschmidt, 2003; Suwa, Purcell, & Gero, 1998), assess them for originality (Brun, Le Masson, & Weil, 2016), and to reflect upon them (Agogino, Song, & Hey, 2007); all of which is lost when outsourcing to T2I generative AI.

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About the Authors:

Alexander "Freddie" Holliman is a Teaching Associate at the University of Strathclyde, in the Department of Design, Manufacturing and Engineering Management. His research interests include: The Practices of Product and Industrial Design Companies, Design-led Research into Complex Project Planning, Product Aesthetics, Novel AI tool use in Design, and Design Education.

Dr Ross Brisco is a Lecturer at the University of Strathclyde, in the Department of Design, Manufacturing and Engineering Management. Ross's research interests include; Computer-Supported Collaborative Design, Design Engineering Education, Novel collaborative technologies including Artificial Intelligence and Virtual Reality to support design, Strategic Technology Selection, Product Design, Development and Realisation.