Skirting the sketch: an analysis of sketch inhibition within contemporary design higher education

Lisa Thurlow, Professor Peter Ford, Grahame Hudson

Author details:

Lisa Thurlow (corresponding author)
School of Design
Room 2.14 VP Building
Faculty Art Design & Humanities
De Montfort University
Leicester LE1 9BH

Email: Lisa.thurlow@dmu.ac.uk
Mobile: 07702 084331

Professor Peter Ford
Nottingham Trent University
50 Shakespeare Street
Nottingham NG1 4FQ

Email: peter.ford@ntu.ac.uk

Grahame Hudson
School of Design
Faculty of Art, Design & Humanities
De Montfort University
Leicester LE1 9BH

Email: g.hudson@dmu.ac.uk

Abstract:

Sketch inhibition is regularly alluded to by educators within design higher education (HE) and one with increasingly marked effects on industry. Over the past thirty years students have been observed to engage less with the manual processes of design development process in favour of other activities perceived as more attractive, to the detriment of their development as effective designers. This paper offers an evaluation of literature which supports the importance of sketching to the design process across a variety of disciplines, its anatomy and functions and demonstrates its role in cognitive support, as a language, a means of reflection, communication and storage of information and the micro-processes it embodies. It also presents observations from teaching practice and initial findings from interviews regarding symptoms of sketch inhibition: from avoidance of studio sessions to an over reliance on digital tools. It considers causes, ranging from lacking skill-sets, psycho-social, to technological and although further investigation is recommended to establish depth and enable development of an appropriate pedagogical framework for its management within HE, various methods are offered at this stage for use by educators: these include fine art exercises, a rigorous pursuit of quantity and even paper type. (195 words)

Skirting the sketch: an analysis of sketch inhibition within contemporary design higher education

1. Introduction

Sketch inhibition is prevalent among higher education design courses in the UK and evidence from the limited sources of literature available supports this, (Booth, Taborda, Ramani, & Reid, 2016; Hu, Booth, & Reid, 2015; Leblanc, 2015). Although continually mooted among educators and industry alike it has, curiously, attracted little interest from academic quarters. Most apparent during studio-based teaching sessions, it appears to be increasing as a phenomenon, its symptoms being embodied in student behaviour and the quality of design output. Industry is subsequently encountering difficulty employing new graduates with the manual ideation skills to fulfil their needs, (Mawford, 2016). Coupled with an increase in the demand for recruits with manual sketching skills, (ibid), there is a growing gap in the skillsets of design graduates, and one that education appears to be have difficulty in addressing. Based upon these initial findings, an investigation into the nature and extent of sketch inhibition among student designers and a proposal for its management is clearly necessary: this paper presents initial finding from an ongoing study into the phenomenon.

2. Context

Research over thirty years by Schenk has provided underpinning for this

investigation (2016). Her observation of the standard of drawing among newly graduated and early career designers is one of decline over the past few decades which as a result impedes activities within industry (2005a) suggesting that secondary education fails to imbue students with drawing skills required for HE studies. Her research also cites inconsistency regarding the importance of drawing within institutions, stating that United Kingdom's Quality Assurance Agency for Higher Education guidelines on the teaching and learning of drawing in higher education institutions are limited to just a single sentence (2005b).

Schenk suggests the teaching of drawing is inconsistent with the needs of designers (2017), and often based on fine art practice as opposed to developing a visual syntax specific to the designer (2005a). She also alludes to friction between the disciplines of fine art and design drawing which serve very different purposes for the designer: those of observation and of conceptualisation respectively, and as such believes the teaching of design drawing should be contextualised within the language of the specific design discipline being studied (2005b).

3. Aim & Objectives

The aim of this study is to establish the nature and extent of sketch inhibition within design higher education (HE), in order to develop a pedagogical tool for its management. To achieve this, a comprehensive understanding of the characteristics and purpose of sketching relevant to the design ideation process was identified as vital.

Sketching serves as a problem-solving tool to many disciplines other than design, (most commonly that of fine and applied art), and individual users relate to it in

very specific and personal ways. However, for the purposes of this investigation a multi-disciplinary approach within design is the focus:

> The practice of designing has common features, regardless of the domain in which it is exercised...No matter what domain, designing involves certain characteristic activities that must be learned, (Gross & Do, 1997).

Thus, a set of objectives was defined as follows: to,

1. Explore the nature, scope, functions and benefits of sketching activity: its purpose within the design process,

2. Explore the internal dialogue and processes of the designer during the design ideation process: its micro-processes,

3. Explore the symptoms and common causal factors of sketch inhibition among student designers, and,

4. Provide an initial set of findings from which a pedagogical framework for the management of sketch inhibition can be developed for design higher education.

4. Methodology

The issue of sketch inhibition has been little considered until recently, with few papers alluding to or explicitly discussing the phenomenon. This lack of evidence revealed the opportunity to apply a Grounded Methodology approach favouring the Straussian (Strauss & Corbin, 1990) method as opposed Glaser's (1992) method which disregards literature. The literature, it was felt, would be vital to the

study. Due to the very limited availability of literature specifically concerning sketch inhibition, a wider approach was taken which considered design sketching in its broader context and sketch inhibition as a phenomenon within that. The review was conducted using both keyword and citation searches and Nvivo, initially for management of the literature, but additionally for meta-analysis.

Observations gathered from an eighteen year period of teaching in higher education have been used as a driver of this study. These helped to identify the initial research need and were used, along with the literature, to structure the subsequent data gathering methods. These were identified through a concurrent analysis/theoretical sampling strategy advocated by the Grounded Theory approach. These observations, together with the literature, formed the basis from which the semi-structured interview questions were developed.

Semi structured interviews were identified at the start of the study as means of "interrogating" (Strauss & Corbin, 1990) the data - to qualify and expand upon issues raised by the literature. These are being conducted among a sample from undergraduate designers, higher education teaching and the design industries and are currently ongoing. The undergraduate sample is composed of sketch inhibited third year students form a variety of disciplines, as per Gross & Do's (1997) concept of discipline non-specificity. Perticipants were identified by their tutors as being sketch inhibited or as struggling to ideate using sketching. Educators were identified as those familiar with and who observed sketch inhibition among their students. Subjects from industry were selected based upon their awareness of sketch inhibition, who were involved in the recruitment of newly graduated designers. Interviews are in progress, the aim to reach a level of "saturation" according to the Grounded Theory approach, where the findings from the data inform the need for further activity: initial findings are incorporated within this paper to support the literature and observations.

5. Key findings from the literature
The purpose of sketching:

This has been widely considered over many years. Ferguson (1992), offers a taxonomy including the 'thinking sketch' as a tool for visual thinking, the

'prescriptive sketch' used for specification of a final solution and the 'talking sketch, (p96-97), used to communicate with others during the design process. Although beneficial in understanding of the role of sketching to design, this early taxonomy is perhaps too simplistic for contemporary consideration.

A more developed taxonomy involving sketches, models, drawings and prototypes is presented by Pei, et al. (2011). Personal, shared, persuasive and handover sketches are further classified. They deconstruct personal sketches into idea, study, referential and memory sketches. The idea sketch is to 'allow the developer to externalise his thoughts quickly' (p12) and is most relevant to this research, as is the study sketch, used to investigate scale, structure and layout based on idea sketches. They consider the referential sketch as one to record information for future use – conversely, memory sketches recall past thoughts. They also identify shared sketches containing annotation that conveys information to members of the design team. Additionally, they classify persuasive sketches, intended to sell a concept, often in the form of a rendered visual that could be presented to a client, and handover sketches, more technically-based images that contain information for manufacture.

On the economy of sketching, marks on the page just *are*, according to Goldschmidt (2003), who proffers that no cognitive energy is used in converting such marks into readable information. She also suggests that sketching can be a representation of linear or diverse thought and acts as a means to test and develop ideas. Goldschmidt coins the term Interactive Imagery - the process of imaging, sketching and resketching images until useful information can be extracted from

them. 'Sketching is not merely an act of representation of a preformulated image…it is more often than not, a search for such an image' (1989, p131).

Cognitive support is a vital aspect of sketch function, enabling offload of what Miller (1956) identified as the brain's limited working memory. Bilda & Gero (2005), through their experiments, also identify issues of working memory limitation during the design process among non-sketchers and the importance of sketching as a means to manage this. Goel's (1995) experiments with graphic designers conclude that freehand sketches 'have an important role to play in human cognition, and they may lie at the root of human creativity' (p189), something the effective designer engages with heavily during ideation.

Sketches combine two types of image - those collected by the eyes and that generated from memory, according to Fish & Scrivener (1990). Observation sketching relying on the repeated refreshing of overt attention to an external image, whereas sketching from memory relies on the generation and manipulation images from the designer's abstract world. Kosslyn (1996) elaborates on this concept, suggesting there are two types of mental representation: propositional and depictive. The propositional representation constitutes a mental sentence whereby the subject creates their own imagery, such as a verbal description or instruction. The depictive representation, of which the sketch is an ideal example, is by contrast an entity with a configuration in a spatial context. The nature of descriptive and depictive information and the relationship between them served by sketching is also considered by Fish & Scrivener (1990): sketching enables the designer to create their own mental images based upon what they see on the page, (referred to as reinterpretation). These images influence that within the designer's mind and can create a cycle of further mental imagery, thereby pushing the design

6

process forward.

Sketching as a language:

Of relevance is the plane of content in which conceptual information is stored, i.e.; the abstract world of the designer's mind. The plane of expression relates to the real world sketching environment where concepts are made manifest. The relationship between these two planes, according to Barthes (1977), creates the designer's own plane of reference and is made from the language of the discipline under consideration, personal experience and the Gestaltising effects of the mind during interpretation. This creates the designer's idiolect – his own personal language used during sketching.

Barthes suggests that the signifier and sign which applies linguistically, as per Saussure, also applies visually, in this instance to the sketch - both scenarios involving a system and syntagm. The system provides the units or language that constitute the syntagm, i.e.; the individual marks and their meaning to the designer. The syntagm is the macro unit of information transmitted; that of the sketch as composed from a collective of marks – Barthes likens this to the spoken sentence. The literal image is a denotation of the abstract form, and the symbolic image is what it means either through idiolect or wider language (1967). 'All images are polysemous; they imply, underlying their signifiers, a "floating chain" of signifieds, the reader able to choose some and ignore others' (1977, p38-39). Particularly pertinent to sketching is the notion that when the symbol is inadequate, the sign outruns its meaning. This can be applied to the complex information contained within design sketches; full of tacit messages that go far

beyond their mere appearance on paper.

Sketching to communicate:

At its most basic level sketching embodies the designer's idiolect, but fulfils more complex functions when in a shared situation. Eckert, et al's (2012), observations of the Across Design Project by the University of Cambridge and MIT, introduces the term 'Conscription device' (p247) to explain the manipulative effect of sketches. Pei, et al. (2011), regard the sketch as an intrinsic language existing between individuals within the design process, and define designer communication using sketches as functioning on four levels: with themselves, with peers, within multidisciplinary design groups and with lay members of the design process, including clients. They cite Star & Griesemer (1989), defining boundary objects as those that convey information to persons of different expertise. Within the context of design, such objects, i.e., sketches, convey information to such persons even though they do not necessarily understand the relevance of that sketch to each other, illustrating the complexity of communication between disciplines within the design process.

Sketching and expertise:

The commitment necessary to gain proficiency in sketching is considered by Bilda et al. (2006): 'as you think you speak…If you think first and then speak, it would all come out differently…It is like a language you learn to talk and it's essential that you do' (p12). This is further endorsed by Barthes (1977) who considers the value of apprenticeship where all codes demand a level of study and application to

be successful in their use. Goldschmidt also observes the importance of expertise for the effective handling of the sketching process: novices often find themselves unable to detach from an image they have created that they are unhappy with, thus forming a negative development within the process. She suggests this is less the case with more experienced designers who have a broader range of experiences to draw upon, (Goldschmidt 1992). Schon & Wiggins (1992) elaborate on this, suggesting the more experienced a designer, the more domains he can work in at once. They note the effects of a lack of experience in respect of working memory limitations, especially where the act of seeing-moving-seeing is required in the management of complexity within a design problem.

Sketching & digital tools:

Sketching by virtue of its nature, is a valuable means of information storage according to Goldschmidt (2003), who suggests that, by default, it allows for access to the history of the creative process whereby complete sets of developmental information can be kept. Digital tools, conversely, tend to consider only the current image and saving design development is not often considered valuable or necessary resulting in much tacit information being lost during the process.

Powell (2017) suggests that the sketch enables representation of 90 per cent of a visual with only ten per cent of the knowing – something that digital tools struggle to offer. Fish & Scrivener (1990) refer to the indeterminacy of manual sketching that enables perception of more than one option at once, and compare this to the computer where the designer can be forced into developmental detail too early,

potentially harming the process. They lament the inability of the computer to offer the serendipity of manual sketching:

> Sketches have the important function of assisting the mind to translate descriptive propositional information into depiction. Depictive information may then be scanned by attentional processes to extract new and perhaps original descriptive information, which in turn can lead to new depiction, (p118).

The dangers of over-reliance on digital tools are cited by Leblanc (2015) among others, suggesting that 'if tools embellish irrelevant ideas, camouflage problems and give students a false sense of accomplishment - or worse, are mistaken for "good design" - then they may need to be called into question' (p6). More specifically, Plimmer & Apperley (2002, quoting Landay 1996) refer to the need for early widget selection when using digital tools, forcing the less experienced user to make decisions about their design too early in the process; the ambiguity that sketching allows is non-existent with such tools. This in turn encourages fixation; the inability to negate inappropriate concepts design the design process.

Fixation is readily seen, particularly among sketch inhibited individuals in studio situations, and according to Cross (1999) it can be both beneficial and detrimental to the quality of design output: avoiding an overload of design information so a design can be established, but with the potential for preventing a design from being effectively developed (2001). Crismond & Adams (2012) warn that fixation 'is pervasive across different design domains and persists despite warnings from

teachers and consultants' (p755) - something any future management protocol needs to consider.

Processes:

The macro- and micro-processes engaged in during sketching enable the designer to make progress within their ideation process. These processes are often misunderstood or not engaged with fully by the novice designer. However, the observation of studio activity has demonstrated that an understanding of the micro-processes encourages positive engagement with sketching and more effective design development.

In regard to these processes, Goldschmidt (1989) devises a 'seeing as' and 'seeing that (p131) structure: 'Seeing as' utilises a Gestalt approach during sketch thinking, using the mind's eye to develop ideas. 'Seeing that' relates to the entity being designed and using the tangible output of the sketch process as a platform for further thinking. 'Moves' and 'arguments' are two distinct types of reasoning embodied by sketching identified during Goldschmidt's experiments at Massachusetts Institute of Technology (MIT), the 'move' being a tangible proposition within the process, and the 'argument' (p35-6) being a conceptual micro-activity within that process. She classifies sketch activity into three distinct areas: 'moves made while actively sketching, moves made while contemplating sketches and reading off them and moves with no graphic input' (1989, p127).

A coding system for sketches is offered by Goel (1995) based on his experiments with graphic designers: lateral transformations occurring within a solution space during the creative shift to alternative concepts:

…when a new idea is generated, a number of variations of it quickly

follow. The variations expand on the problem space…One actual gets the

sense that the exploration and transformation of ideas is happening on the

paper in front of one's eyes as the subject moves from sketch to sketch,

(p200).

Conversely, he identifies vertical transformations during the sequential

development of a concept towards a solution and identifies reinterpretation as a

vital function of sketches, allowing the observer to apply new meaning to an

existing set of information.

Designers are involved in a 'transactional' relationship with the design and are in

a 'reflective conversation with the situation' according to Schon (1991, p4). 'The

act of drawing can be rapid and spontaneous, but the residual traces are

stable…the graphic world of the sketchpad is the medium of reflection-in-action'

(Schon 1983, p153). He suggests that design episodes involve apprehension of

material situations though sensory appreciation, and proposes that the designer

constructs an abstract world of objects and relationships through which he

addresses the design problem (1991). Similar to Goldschmidt's proposition of

'seeing as' and 'seeing that'(1989, p131), he refers to the process of 'Seeing-

drawing-seeing' - 'a designer sees moves and sees again' (p7). His notion of

seeing embraces the use of faculties other than sight; the terms 'recognise, detect,

discover and appreciate' (p7), are proposed to reinforce the concept of design

being a bodily process.

According to Cross (2001, referring to Akin & Akin 1996), in order to create new

concepts, the designer's frame of reference needs to be broken, presenting opportunities for creative re-interpretation, such shifts in mode between drawing, examining and thinking enable design discoveries to be made. Gathering information, drawing and reflection in combination with quick switches between these modes, he suggests, are deemed to be conducive to the most successful progress in design problem-solving. Bilda et al. (2006, p12), consider this in more detail: 'Half the process is drawing it, and drawing it….and eventually…something sort of creeps out at you.' They consider the concept of re-representation via their protocol analysis experiments and establish that sketching imparts a dialogue: 'you can't stop the messages coming back from each line you put down' (p12). They observe the Gestalt nature of elements within the sketch, '…seeing it in parts and seeing it as a whole…the whole emerges from and cannot exist without the parts but depends on the relationship between the parts' (ibid). The importance of externalisation of mental imagery is vital to the designer: 'the vision is in your mind and then you are putting it down…it is the image (that) moves the pencil' (ibid).

6. Observations

These have been collected during teaching practice since 1999 and are ongoing. They suggest that sketch inhibition in affected students is embodied in a reluctance to physically place pen onto substrate, and a tendency towards use of metal imagery alone to develop concepts. Sufferers demonstrate a tendency to favour temporary mark-making tools such as pencil and are often seen to over-use erasers to remove unsatisfactory developmental marks. There exists a tendency for sufferers to produce smaller sketches than their fluent peers, these often positioned in the corners of pages, together with a refusal to work in larger

formats. Over-rendering of sketches is identified, as is poor or weak line quality.

Refusal to participate has been observed among sufferers, some preferring to play with mobile phones during studio session rather than mark-make. Requesting to leave sessions where sketching is required is also seen, sufferers maintaining they cannot, for various reasons, work in the studio.

Tearfulness has been observed on occasion as students suffer the pressure of being required to perform without, as they perceive, the confidence or skills to undertake the task. When required to submit development material for their design projects, inhibited students commonly convey their design concepts as collected images with little analysis or development between such images and their final design.

In interview, Fitton (2016) supports the observations of sketch inhibition during studio design tasks:

> They just pretend they're doing it, don't do it, or do just a part of it…sometimes they stop coming to their sessions (and) tutorials because they're embarrassed…then they present their sketchbooks (with) as few as four pages of drawings.

Complaints about being unable to think on paper are regularly made by students, those affected maintaining that digital tools are the only means to develop their ideas. During one observed studio session, inhibited students within a group of undergraduates relied solely on CAD to develop their ideas. These ranged from naïve repeated elements, all straight-line-based, to those containing CAD blocks available online. Some design output from this session looked impressive,

utilising the benefits of computers, but the results all had the same commonalities - poorly developed concepts combined with a CAD aesthetic. Coyne, et al. (2002), acknowledge this type of inexperience with CAD as problematic in enabling students to realise their ideas: 'If you only know how to draw a box, your building will be a box, and if you know how to design anything on the computer you can design anything' (p270).

Booth, et al. (2016) identify several types of sketch inhibition during the design process, classifying three distinct areas:

Issues of the individual, including:

- intellectual inhibition, or a lack of awareness of the benefit of sketching to the design process,

- Skill-set inhibition; the lack of expertise needed to use sketching effectively,

- Personal inhibition; ego-driven issues of perfectionism that impair the creative flow, and,

- Situational inhibition, when a designer does not feel in the right state of mind to sketch.

Secondly, social issues, including,

- Social and comparative inhibition or the fear of being judged unfavourably by others during the process of creating sketch material, and,

- Social loafing embodying a lack of input in a group situation, either through fear of judgement or laziness.

The third area Booth et al. identify is that of technological inhibition caused by a prevalence of digital tools available in the designer's environment leading to a disinterest in manual sketching, (Booth et al., 2016).

7.   Causal factors

These have been identified at this stage via the literature as belonging to the broadly distinct areas of psycho-social, intellectual, skill-set and technological, or a combination of these. Fear of failure, as mentioned above by Booth et al. (2016), is also identified by Leblanc (2015), who suggests that 'the development process is widely misunderstood or inaccessible' (p2), and has resulted in a common belief among students that experimentation and failure within design process are somehow unacceptable. Because of this fear, students rush into visualisation as soon as they have a suggestion of a concept, omitting stages of evaluation essential for a fully developed design solution.

Leblanc's (2015) research with industrial design students demonstrates the lack of intellectual awareness among students, who:

> …struggle with the creative process, especially with sketching, exploring and developing ideas into mature designs. Many see sketching only as a means of visualization and rarely know how to use it as a creative thinking tool, (p1).

She also suggests an over-reliance on technology as a causal factor:

> Students are judged by their skills with these tools rather than their creativity or problem-solving ability…(which)…nurtures the

misconception of design as an aesthetic gesture rather than an intellectual, creative thought process that helps solve problems and drive innovation, (p5).

The essential processes of design embodied by its practical activities have been replaced with what she describes as 'more gratifying digital tools' (p2).

The culture of immediacy among millennial learners (Skiba, 2005) appears to be a causal factor of sketch inhibition and it is debatable whether sufferers of sketch inhibition would invest their energy in developing a skill-set. One industry interview revealed:

> A lot of people sort of say "oh, I'd love to be able to sketch" and I say "well, you can if you try hard enough" but there seems to be an unwillingness to spend the time… Over the last 15 years… (the) reliance (is) on software to provide the answers rather than a deep thinking process. (Mawford, 2016).

Interestingly, the expansion in the number of higher education design courses over recent decades may have, ironically, had a part to play in an increase of inhibited students. Some institutions now apply a less rigorous approach to recruitment, Lambert & Firth (2006) observing 'Applicants no longer have to compete against each other, and consequently students' drawing skills upon embarking on a design degree are generally much less adept than in the 1980s' (p5).

8.   Management of sketch inhibition

The management of sketch inhibition is barely touched upon anywhere in the literature and remains a conundrum among educators who often apply their own varied approaches. It has however, been addressed by Hu et al. (2015), who consider how warm-up exercises among engineering students affect their cognitive states during concept development. They concluded that art-based exercises were helpful in encouraging concept generation and appeared to benefit younger participants most. Female participants unexpectedly expressed an increase in pride in their sketch output after the exercises. This suggests that management of sketch inhibition is possible and shows further potential for this research.

Leblanc's (2015) research suggests the attitude of the individual is vital in overcoming sketch inhibition. She suggests 'those with high ambitions and strong self-motivation manage to overcome the deficit' (p2) and believes that those with the determination to develop and maintain new skills have a good chance of becoming fluent and confident sketchers – however, creating that motivation among inhibited students will be the challenge for educators. Leblanc (2017) favours quantity of sketch output: requiring students to produce up to 100 thumbnails effectively pushes them towards credible concepts. Booth (2017) considers that quantity is also important, going beyond eight or nine concepts allows the student to reach an effective level of creativity, but warns of burn-out where the mind fades and students resort to stuffing their development work with meaningless images to fulfil their brief.

Schenk (2017) cites the importance of purposeful observation drawing instead of traditional life drawing to improve student skill-set: she believes that standing at easels engaging in life drawing does not assist students –observation drawing needs to be tailored to specific purpose, i.e., studies of anatomy where it specifically supports the need of the design discipline. She has also observed the benefits of taking a less precious approach to sketching by using cheap newsprint and pots of school paint during studio exercises, proving that expensive sketchbooks in themselves have an inhibiting effect.

9. Conclusions & recommendations

This research presents an account of the value of sketching to design, but curiously an overwhelming majority of students, (and educators), are unaware of its full potential. Unlike the humanities and sciences where there is a tradition of sharing research and imbuing findings within practice, design appears to suffer a vacuum between research and education - 'designers don't read, so design writers don't write '(Kalman, T. et al, 1991): this is not always the case, but appears to apply in respect of design ideation sketching.

There exists little data regarding the causes and symptoms of sketch inhibition and its management within HE. Student understanding of sketching purpose and process and its teaching appears to rely on individual input from tutors with often disparate understandings of the skill and their own agendas. However, a number of issues have emerged from the research which are of relevance:

1. The importance of educator and student awareness of the functions of sketching and its benefit to design in order to support a rational process

during design ideation. Rather than students deferring their creativity from analogue to digital process with no understanding of the differences between the two, greater understanding of the purpose of and processes within sketching could enable them to make more appropriate choices about their approaches.

2. The need for greater student confidence to connect with the indeterminacies of the design process without fear of 'failure' in front of peers. The lateral, re-interpretive functions that sketching provides could persuade the inhibited individual to engage with the design process with less anxiety (rather than to cling onto a simplistic, linear approach), and warrants further investigation. Tools for this approach could include encouraging improved motor skills through fine art exercises, and the use of non-precious materials and substrates during ideation to avoid fixation. Purposeful observation that benefits the specific design discipline, rather than a broad fine-art approach to drawing tuition, together with support of skills through maintenance activities would also be of benefit.

3. Greater structure in the pedagogy of teaching sketching could be of potential benefit rather than assuming it is a purely intuitive process. However, student resistance may be an issue, based on Skiba's (2005) observations , and those of design educators: 'We're all a bit timid about pushing students to do things that they don't want to do, and I think you have to' (Fitton, 2016). A longitudinal approach to the teaching, learning and maintenance of sketching skills throughout an entire course could

serve this need. Pursuing quantity of output in a structured rather than intuitive approach to sketching could help signify the importance of the skill as a creative and cognitive tool within the student's own practice.

Further qualitative research into these issues is essential, with the need for extensive primary data in order to build a more accurate picture of sketch inhibition as a phenomenon and to qualify the initial proposed approaches for its management. This activity will enable development of a fully tested pedagogical framework for the management of sketch inhibition among undergraduate designers across the disciplines.

Bibliography

Akin, Ö., & Akin, C. (1996). Frames of reference in architectural design: analysing the hyper-acclamation (Aha-!). *Design Studies,* Vol. 17, No. 4, pp. 341–361.

Barthes, R. (1967). *Elements of Semiology.* London: Jonathan Cape.

Barthes, R. (1977). *Image, Music, Text,* St Ives, UK: Clays Ltd.

Bilda, Z., & Gero, J. (2005). Does sketching off-load visuo-spatial working memory? *Studying Designers,* (1986), pp. 145–159.

Bilda, Z., Gero, J. S., & Purcell, T. (2006). To sketch or not to sketch? That is the question. *Design Studies,* Vol. 27, No.5, pp. 587–613.

Booth, J. W., Taborda, E. A., Ramani, K., & Reid, T. (2016). Interventions for teaching sketching skills and reducing inhibition for novice engineering designers. *Design Studies,* Vol. 43, pp. 1–23.

Booth, J. (2017). Post-doctoral researcher, Yale University, USA - *Interview*.

Coyne, R., Park, H., & Wiszniewski, D. (2002). Design devices: digital drawing and the pursuit of difference. *Philosophy of Design*, Vol. 23, No. 3, pp. 263–286.

Crismond, D., Adams, R. (2012). The Informed Design Teaching and Learning Matrix - ProQuest. *Journal of Engineering Design*, Vol. 101, No. 4, pp. 738–797.

Cross, N. (1999). Natural intelligence in design. *Design Studies*, Vol. 20, No. 1, pp. 25–39.

Cross, N. (2001). Design cognition: Results from protocol and other empirical studies of design activity. *Design Knowing & Learning: Cognition in Design Education,* pp. 79–103.

Eckert, C., Blackwell, A. F., Stacey, M., Earl, C., & Church, L. (2012). Sketching across design domains: Roles and formalities. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing,* Vol. 26, No. 3, pp. 245–266.

Ferguson, E. (1992). *Engineering and the Mind's Eye.* Cambridge, MA: MIT Press.

Fish, J., & Scrivener, S. (1990). Amplifying the mind's eye: sketching and visual cognition. *Leonardo*, pp. 117–126.

Fitton, R., (2016), Head of Interior Design, De Montfort University, Leicester, UK - *interview*

Glaser, B.G. (1992), *Emergence vs forcing: Basics of grounded theory analysis*, Sociology Press.

Goel, V. (1995). Sketches of Thought: A Study of the Role of Sketching in Design Problem-Solving and its Implications for the Computational Theory of Mind. *Dissertation;* University of California, Berkeley.

Goldschmidt, G, (1989), Sketching in Design - Past, Present, Future. In *Proceedings of the Environmental Research Design Association,* North Carolina State University, USA, pp. 132-138.

Goldschmidt, G. (2003). The Backtalk of Self-Generated Sketches. *Design Issues,* Vol. 19, No. 1, pp. 72–88.

Goldschmidt, G. (1992). Serial Sketching: Visual Problem Solving in Designing. *Cybernetics and Systems*, Vol. 23, No. 2, pp. 191–219.

Gross, M. D., & Do, E. Y. L. (1997). The design studio approach: learning design in architecture education. *Design Education Workshop*, EduTech/NSF, College of Computing, Georgia Institute of Technology, September, 8–9.

Hu, W.-L., Booth, J., & Reid, T. (2015). Reducing Sketch Inhibition During Concept Generation: Psychophysiological Evidence of the Effect of Interventions. In *ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers.

Kalman, T., Miller, J.A., Jacobs, K. (1991). Good History, Bad History. *Print Magazine*, Vol. 1, pp. 25–33.

Kosslyn, S. M. (1996). *Image and brain: The resolution of the imagery debate.* USA, MIT press.

Lambert, I., & Firth, R. (2006). Pencils Don't Crash. In *DS 38: Proceedings of E&DPE 2006, the 8th International Conference on Engineering and Product Design Education*, Salzburg, Austria,7-8 September 2006.

Landay, J. (1996). Interactive sketching for the early design stages of user interface design. *PhD;* Carnegie Mellon University, Pittsburgh, PA.

Leblanc, T. (2015). Sketching as a Thinking Process. In *DS82: Proceedings of the 17th International Conference on Engineering and Product Design Education (E&PDE15), Great Expectations: Design Teaching, Research & Enterprise.*

Leblanc, T, (2017). Associate Professor, University of Montreal, Canada – *Interview.*

Mawford, J., (2016), Director Z Solutions, Suffolk – *Interview.*

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, Vol. 6, No. 2, p. 81.

Pei, E., Campbell, I., & Evans, M. (2011). A taxonomic classification of visual design representations used by industrial designers and engineering designers. *The Design Journal,* Vol. 14, No. 1, pp. 64–91.

Plimmer, B., & Apperley, M. (2002). Computer-aided sketching to capture preliminary design. *Australian Computer Science Communications*, Vol. 24, pp. 9–12.

Powell, D. (2017). Director, Seymour Powell, London - *Interview*.

Schenk, P. (2005). Reflections on the teaching of drawing in the digital age : attitudes of senior academics in the United Kingdom to the place of drawing tuition on the design curriculum in higher education. *Art, Design & Communication in Higher Education, Vol.* 4, No. 3, pp. 189–203.

Schenk, P. (2005). The Why and How of Drawing: A 20 Year Shift in Design Procedures and Priorities. In *European Academy of Design Conference* pp. 1–11.

Schenk, P. (2017), Visiting Research Professor of Textiles & Design, Heriot Watt University, Edinburgh - *Interview*.

Schön, D., Wiggins, G, D. (1992). Kinds of Seeing and their Functions in Designing. *Design Studies,* Vol. 13, No. 2, p. 135.

Schön, D. (1991). Designing as a reflective conversation with the materials of a design situation. In *Edinburgh Conference on Artificial Intelligence in Design*, pp. 1–50

Schön, D. (1983). *The Reflective Practitioner: How Professionals Think in Action,* New York: Basic Books.

Skiba, D. J. (2005). The Millennials: have they arrived at your school of nursing? *Nursing Education Perspectives*, Vol. 26, No. 1, pp. 370–371.

Star, S., & Griesemer, J. (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science,* Vol. 19, No. 3, pp. 387–420.

Strauss, A. & Corbin, J.M. (1990), *Basics of qualitative research: Grounded theory procedures and techniques*, Sage Publications, Inc.