

Materials in footwear: an empirical study of hands-on textile approaches to sandal design

Jenny Gordon, Loughborough University, UK

Faith Kane, Loughborough University, UK

Mark Evans, Loughborough University, UK

Abstract

Commercial sandals are often designed in a 2D format and materials are generally applied during design development rather than the earlier stages of the process. In contrast, hands-on woven textile design is often carried out through making and interaction with materials. This paper presents the findings of an action research case study that investigated the use of 'hands-on' woven textile approaches to sandal design at different stages of the design process. The role that hands-on interaction with materials plays at each stage is analysed to assess areas of potential for its integration. The case study presented in this paper focuses on an aspect of wider research that investigates the potential for innovation through hands-on interaction with materials in the sandal design process.

The research questions for the study are: is there potential for the in-depth knowledge of materials and construction gained through a hands-on approach to be applied in the sandal design process; where and how does it have the potential to be integrated; how does the use of hands-on interaction with materials compare with more conventional approaches at different stages of the design process?

The case study was undertaken in the form of a sandal design project that incorporated the use of hands-on woven textile approaches. The designs produced were informed by knowledge generated through hands-on weaving techniques. The discussion of the empirical research refers to a literature review that was conducted alongside this case study. The findings indicate that there is potential for a hands-on woven textile approach to sandal design and it may be integrated at all stages of the design process. Key challenges were noted in relation to issues of time and cost efficiency in comparison to using conventional footwear design approaches alone. Benefits in terms of opportunity for innovation, generation of in-depth knowledge and immediacy, along with control in decision-making are discussed. Hybrid approaches are also identified as being suitable for bringing together outcomes that consist of a number of different formats.

Keywords

Woven textiles; Footwear; Hands-on design; Practice-based research; Material interaction

Woven textile design processes often rely on making as a method of generating and realising design ideas whereas footwear design more commonly relies on the use of 2D approaches such as drawing (using CAD or by hand). Through hands-on interaction with materials, intimate and experiential knowledge is gained of the materials and construction (Philpott, 2012, p. 69; Sennett, 2009, p. 160). This paper reports on an action research case study that investigates the use of hands-on woven textile approaches to sandal design. The case study forms part of wider research into the potential for hands-on woven textile approaches to facilitate innovation. An overview of the wider research context is presented in Figure 1 and includes data collection through additional case studies and interviews with designers. The case study presented in this paper consists of a design project that uses hands-on interaction with materials as a method of design and development. The potential for the integration of woven textile processes with sandal design is

discussed and comparisons between design approaches are drawn. Categorised according to whether they are 2D, 3D, digital, non-digital or hybrid, the roles these methods of design played are presented. The findings are relevant to the design and craft industries and academia through contribution to knowledge of design approaches and the role of making and interaction with materials in design.

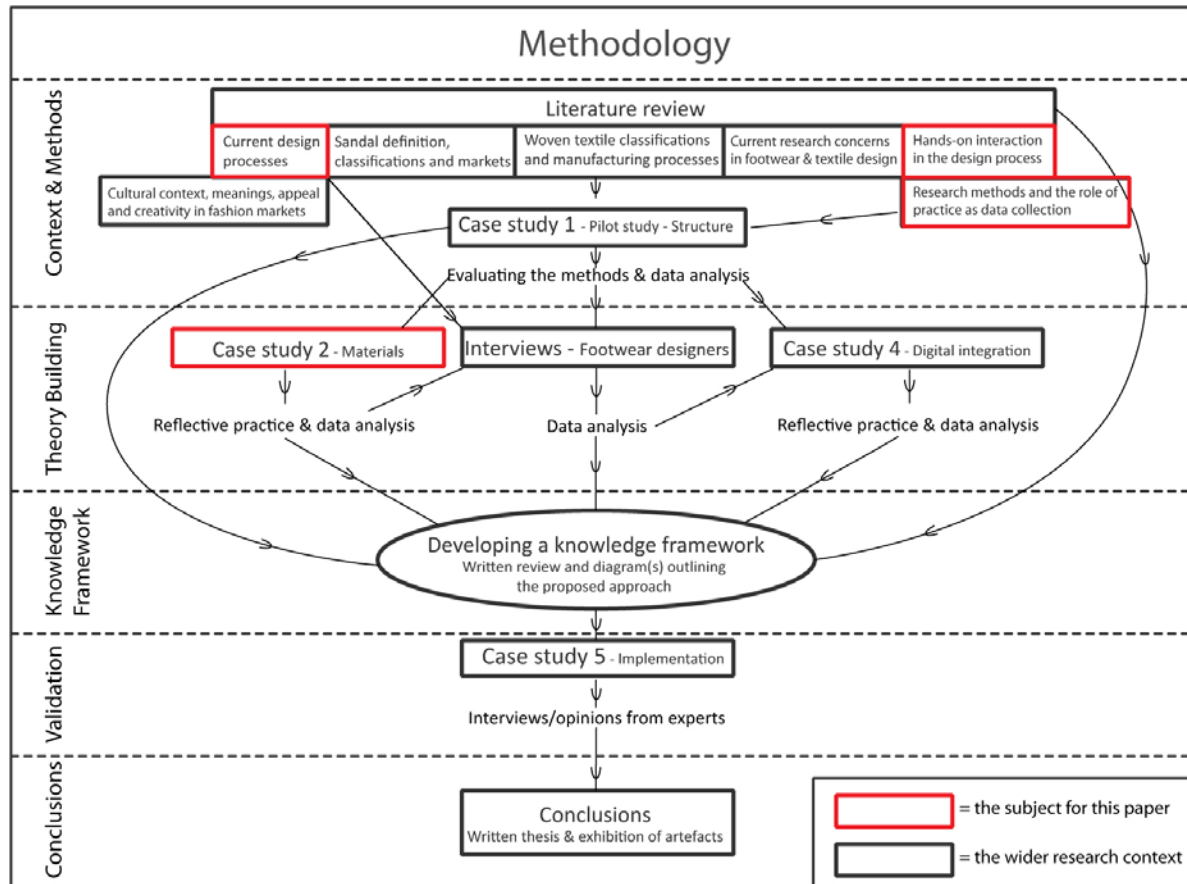


Figure 1. A diagram showing the practice-based case study within the wider research context

The roles of differing approaches are investigated at different stages of the design process. These stages have been defined by the data and a model of the general design process as presented by Wilson (2011, p.58). They consist of concept development; initial research; in-depth research; idea generation; design development and presentation. The literature review focuses on two of these stages, 'idea generation' and 'design development' allowing for the comparison of the use of different approaches in explorative (idea generation) and practical (design development) stages.

Approaches to design: Idea generation

This section discusses three contrasting approaches to the design process at the 'idea generation' stage. This is the point when design ideas are conceived. The stage is creative and holistic and occurs before an idea is developed and made to work in a practical sense (Tovey, 1997, p.10).

Sketching and drawing

Drawing by hand is a common method used in footwear and other disciplines in order to generate ideas. It has been noted as crucial to the creative process (Lawson & Loke, 1997, p. 172) and Purcell and Gero (1998, p. 392) describe how drawing can develop the form of a physical object. They describe how information is drawn

from the long-term memory during this process along with bringing attention to alternative aspects of a design, leading to novel interpretations. This idea was previously introduced by Schön (1992, p.5) who describes the design approach as “seeing-drawing-seeing” and states that this process aids the generation and evolution of design ideas. A detailed and ingrained knowledge of a design can be gained through the drawing and re-drawing of a form by hand.

Computer based methods

The use of digital design methods can yield a number of benefits, such as the ability to speed up the design process (Cross, 2001, p. 46; Sennett, 2009, p. 39; Sweet, 2013, p. 31; Tovey, 1997, p. 18) and create variations on a design with ease (Zaman, Özkar & Çagdas, 2011, p.225; Zequn & Rui, 2010, p.223). It also allows designers to generate complex forms and visuals that would not be possible otherwise (Lawson, 2002, p. 327; Philpott, 2012, p. 56; Sweet, 2013, p. 31) and it is this potential for new opportunities rather than the imitation of existing ones that is seen as important in order for CAD to aid creativity (Lawson, 2002, p.327). It has been found in a number of studies that the use of CAD/CAM in the early stages of the design process can restrict creativity and spontaneity (Evans et al., 2000, p. 189; Lawson & Loke, 1997, p. 174; Treadaway, 2007, p.46) and only when software can be used instinctively can it provide advantages in creative innovation (Lawson, 2002, p.327). The sole use of CAD/CAM in the design process removes materiality and also the ability to gain embodied knowledge through touch (Philpott, 2012, p.60) that can build in-depth knowledge of processes and materials. Hands-on computing solutions are being developed with the aim of providing a suitable method that suffices both creative and practical needs (Evans, Wallace, Cheshire & Sener, 2005, p.489). However, it appears that, at present, technology has not been developed to a stage where it can successfully replicate real interaction with materials as an instinctive process (Evans, Cheshire & Dean, 2000, p. 193; Philpott, 2012, p. 60).

Material interaction

In hands-on woven textile design, the early stage of idea generation usually consists of sampling on a loom, during which the designer will experiment with different colours, structures, and yarns (Wilson, 2001, p.14-15). Touch is particularly important in textiles (Philpott, 2012, p.54); making and interaction with actual materials can contribute to the development of form (Leader, 2010, p. 413; Philpott, 2012, p. 54) along with informing creative thought (Treadaway, 2007, p.35). In some situations, hands-on making can also contribute to the development of novel materials (Yair & Schwarz, 2011, p. 312) meaning that it is a viable approach to innovation within the discipline.

Flaws in materials can be identified by developing and experiencing them first-hand in the early stages of a design project (Sennett, 2009, p.159), allowing adjustments to be made. It is possible for CAD systems to store and use information of material properties in order to undergo testing in a digital format. Such software is being developed within the performance textile industry (Adanur & Vakalapudi, 2013, p.716) to address the need for designs to be tested at an early stage in order to speed up the design process. This example is from a function-led industry, however, in creative design, products also evolve through a number of subjective alterations (Wallace & Press, 2004, p. 42).

Although there is the potential for significant advantages in the use of making as a tool for idea generation, it may not always be possible to work in this way due to practical constraints. Within the context of using a woven textile approach to sandal design, one problem could lie in the availability of weaving equipment which is generally bulky and noisy. Time and cost are the main challenges, with hands-on making often being a slow and expensive process (Philpott, 2012, p.61). This must

be compensated for elsewhere in the design and development cycle or have significant benefits in the final outcome.

Approaches to design: Design development

Design development is the point at which the design ideas are developed and refined and so has a more functional/practical objective than the idea generation stage. This section discusses the role different outputs of the design process have to play at this stage.

Two-dimensional representations

Drawing by hand or with CAD software can be used to create 2D technical working drawings of a design. These are common within footwear design and specification sheets are generally used to communicate design ideas to the sample room for prototypes to be constructed (Schaffer & Saunders, 2012, p.156). However, there are limitations for a two-dimensional approach to communicating details of three-dimensional products (Tovey, 1997, p.26). For example, when refining a design on paper or on screen, it is possible that the scale and proportions may look correct but that they may not translate into three-dimensions (Glanville, Worswick & Golding, 1934, p.103; Sennett, 2009, p.41). This means that there is potential for misinterpretation and 2D representations may lead to issues in understanding. However, the time efficiencies of this method are much greater than that of three-dimensional ones (Tovey, 1997, p.11).

CAD drawings can easily depict a number of variations of a design (Philpott, 2012, p.60) and central databases can organise design work and supporting information (Tovey, 1997, p.18). The use of two-dimensional representations is common in the communication of designs within the footwear industry (Schaffer & Saunders, 2012, p.156-157). Therefore, this must be considered for the successful integration of novel approaches, which could support current methods rather than fully replace them.

Three-dimensional representations

Three-dimensional representations can be created using CAD software to generate digital models or through the use of modeling materials which are different to the actual material and construction to be used. The ability to see an object in 3D can allow for the form to be refined, providing a “higher degree of realism” (Jimeno-Morenilla, Sánchez-Romero & Salas-Pérez, 2013, p.1371) in comparison to 2D representations.

Digital 3D models can speed up design and development (Cross, 2001, p. 46; Sennett, 2009, p. 39; Sweet, 2013, p. 31; Tovey, 1997, p. 18) and aid accuracy (Sennett, 2009, p. 81), reliability, in terms of memory (Lawson, 2002, p.328), and organisation (Tovey, 1997, p.18). The availability of rapid prototyping has meant that CAD/CAM methods are now much more accessible (Evans et al., 2000, p.188; Philpott, 2012, p.69) giving designers the ability to model designs physically. The disadvantage to using 3D CAD as opposed to physically modeling an object is that what is produced on screen is actually a 2D representation of the 3D model and manipulation of that model may lack control (Joneja & Kit, 2013, p.252). The majority of benefits of CAD/CAM systems appear to relate to efficiency, cost and other factors that do not contribute to creative thought processes. However, in footwear design digital 3D modeling can actually slow down the design process (Antemie, Harnagea & Popp, 2012, p.415) and hands-on/physical methods are generally used (Zequin & Rui, 2010, p.222). Improvements in efficiency could potentially apply to footwear design, if more appropriate software was developed (Antemie et al., 2012, p.415; Azariadis, 2013, p.321).

Physical artefacts/actual materials

A wealth of knowledge can be gained from objects (Cross, 1982, p.224) and designs can often be misinterpreted (Schön, 1992, p.5), however, it is conceivable that designs in the form of actual objects are less likely to be misunderstood as they may be reproduced almost directly. The process of creating a physical prototype of the end product can also extend the designer's knowledge of "materials, processes and technologies" (Lommerse, Eggleston & Brankovic, 2011, p.391) and in turn, there may be a greater chance of success in the outcome.

While there are limitations associated with communicating designs using representational media (Sweet, 2013, p.391; Tovey, 1997, p.26) success in its use can be aided by knowledge gained through prior design experiences (Cross, 2004, p.432). When using constructions, processes and materials which are widely known, the use of artefacts within the product development process may not return many, if any, advantages. Knowledge can be gained through both making by hand and other representational design activities (Schön, 1992, p.4). However, the way in which designs are presented and translated by product development teams and manufacturers is another consideration. Meaning that an expert designer may be able to use prior knowledge to generate ideas that will work in practice, however, if they are not conveyed effectively to the people constructing them, then time may be wasted through unsuccessful sampling. Transportation of physical samples presents issues regarding efficiency, however, the benefits could make the transportation worthwhile.

Methods

A practice-based case study was undertaken in the form of a sandal design project led by in-depth research of materials through weaving. The design process integrated hands-on woven textile approaches with conventional footwear design methods (see Figure 2 for examples).

Practitioner as researcher

The primary researcher's background and experience as a footwear and textile designer was pertinent to the decision of employing practice as a research method. Nimkulrat (2012, p.1) states that, "positioning craft practice in a research context can facilitate the reflection and articulation of knowledge generated from within the researcher-practitioners artistic experience, so that the knowledge becomes explicit as a written text or as a means of visual representation." Similarly, Evans (2010, p.8) presents the theory that practice and reflection can access knowledge that may not be derivable from other sources and this is the reason for its use. There are difficulties associated with the communication of tacit knowledge and the ability of an expert to make design decisions/judgments based on their experience is not a straightforward subject for data collection. Niedderer and Townsend (2010, p.8) identified that tacit knowledge can be recorded, in part, by documentation through both written and visual media. In this case study the outputs of practice along with written and visual documentation are all considered forms of data.

Action research and case studies

Case studies were identified as an appropriate research method due to the ability to collect data that is rich in detail and empirically relevant/valid (Eisenhardt, 2002, p.29). The case study was undertaken using action research which is described by Birley and Moreland (1998, p.34) as "research conducted by a professional into their own activity with a view to bringing about an improvement in their practice." The professional experience of the primary researcher means that this method is applicable and valuable in discovering and evolving processes through practice.

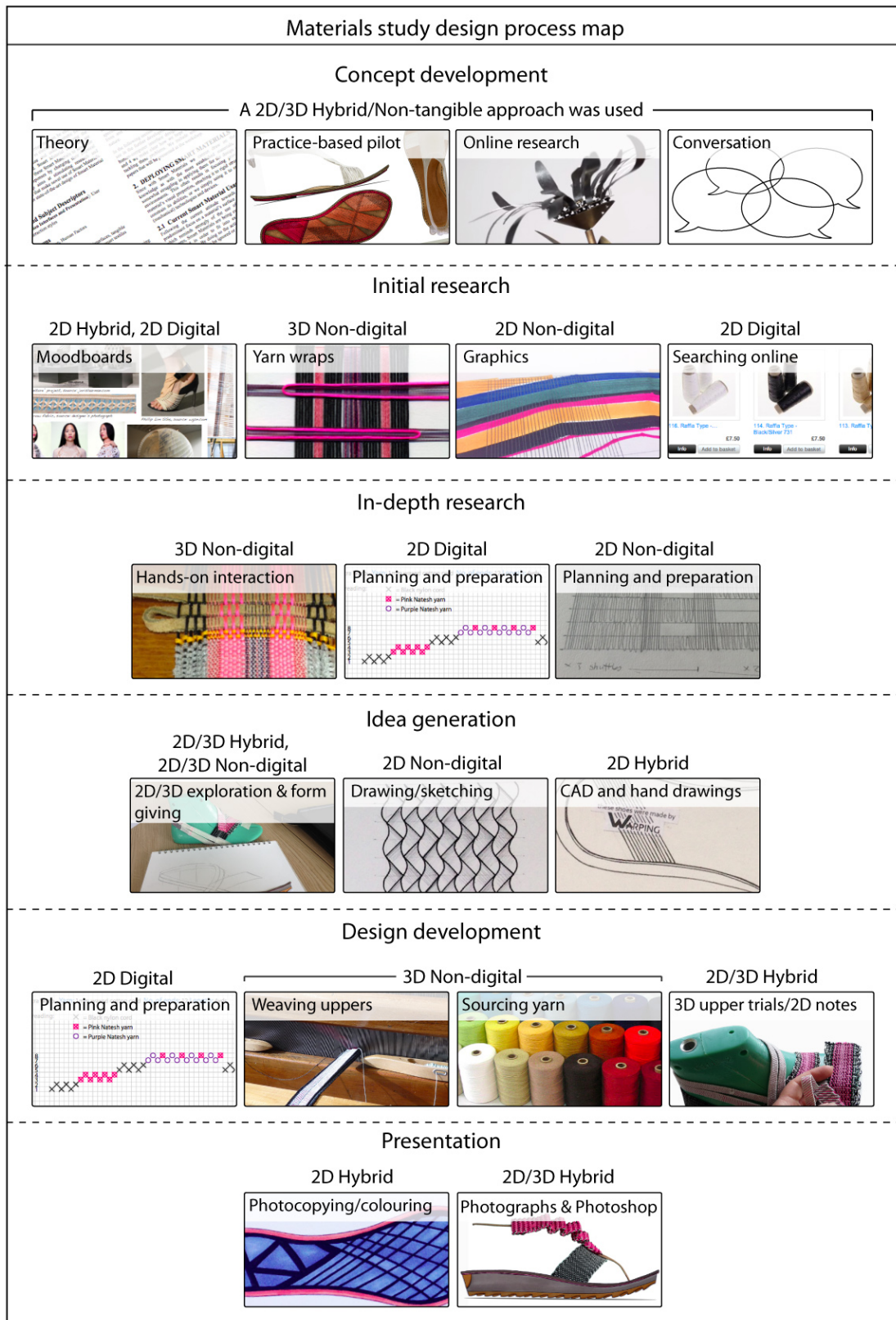


Figure 2. A diagram of the design process and methods used in the case study

Data collection

Diaries, and more specifically “end-of-the day reporting” (Pedgley, 1997, p.220) were used as the main method of recording the design process. Pedgley (2007; 1997) identified them as striking a balance between accuracy of information and interference with the normal design process. This balance was important to the research and this, along with the ability to record and link a number of different data formats formed the reasoning for its use.

While diary entries were the main method of documentation, data collection was undertaken in a number of formats:

- Diary entries
- Diary log
- Supporting documents
- Sketchbook pages
- Physical artefacts
- Design sheets
- Digital files

The diary entries, diary log and supporting documents were used to keep track of all activities within the case study. Examples are shown in Figure 3 to 5. The additional data formats consisted of the outcomes of the design project; these aided the researcher in building a full picture of the design process for analysis.

Weave as a method of sandal design:
Case study II "materials" - Diary

Sheet number: 18
Date (dd/mm/yy): 22/01/15

Design log

Activity:
Designing an upper based on the shape holding properties of Warp 2.

Activity function (e.g. generate design ideas):
Generate design ideas.

Corresponding article/design ID: S83020-73 Supporting documents/notes ID: SD07

Diary notes

I began by making notes to explore the potential for this material. The notes focused on what the material properties could bring to the design along with some loose ideas for application.

I then went on to generate some ideas using the Warp 2 samples and fitting them around the last. This then informed some sketches which in turn helped to plan a possible warp, also through sketching.

It brought the project back in line with creating footwear and it was now possible to see where the exploration of materials still could fit.


However, it seems clear that the exploration of materials at the research stage, while valuable, cannot guarantee results. The properties were happened upon by accident and it is still to be seen how they can be used effectively in footwear design.

Figure 3. An example of a diary entry used to document the process


Date (dd/mm/yyyy)	Activity	Time (hrs)	Diary Sheet number	Article/design ID code	Supporting material ID code	Comments
02/02/15	Weaving upper designs and finishing them/putting them on the last	3	21	Warp 3	SD020	
04/02/15	Evaluating samples for uppers 1 and 3 and making changes/suggestions, then weaving upper 1 with some changes made.	6	22	SB3026-27, Uppers 1 & 3, warp 3	NA	
05/02/15	Weaving variations on upper 1 based on the evaluation of the 1st sample	4	NA	Warp 3	NA	This was more of a practical task, I will evaluate the outcomes and make judgements on them off the loom
17/02/15	Designing an outsole and drafting warp 4	2	NA	DS029-30, DF023	NA	
18/02/15	Designing an outsole	4	23	DS031-33	NA	
19/02/15	Designing an outsole and logo	4	NA	DS033-34, SB3028, DF024	NA	
25/02/15	Colouring outsole designs	2	24	DS035-37	NA	
05/03/15	Altering weave draft and setting up the loom	5	25	Warp 4; DF023	NA	
06/03/15	Weaving an upper design relating to SB3026	4	26	Warp 4	SD021	
10/03/15	Finishing weaving and cutting off and finishing the upper relating to SB3026	2	NA	Warp 4	NA	
12/03/15	Weaving a second sample relating to SB3026	2.5	27	Warp 4	SD022	
13/03/15	Manipulating sample 1 from warp 4 in order to generate some additional design ideas and weaving a sample based on sample 1	4	28	SB3029-31, Warp 4	SD023	
18/03/15	Started weaving a sample based on SB3029-30 and sourcing yarn	0.5	29	Warp 4	NA	
19/03/15	Weaving a sample based on SB3029-30	5	30	Warp 4	NA	
20/03/15	Weaving a sample based on SB3029-30	1.5	NA	Warp 4	NA	The sample was finished and the warp cut off the loom


Figure 4. An image of the diary log used to document the design process

Jenny Gordon
'Materials' case study II SD017- 22/01/15




Samples from warp 2 are used to generate design ideas






The fabrics on the last were used to identify measurements for the design.

The sandal was sketched



And the weave was planned out on paper



Samples from warp 2 were placed on the last in order to generate design ideas incorporating the handle and properties of the nylon textile. Folded elements were identified as having potential and I came up with the idea to include a cord so that the wearer can change the look of the sandal, i.e. pleats or no pleats.

Figure 5. An example of a supporting document used to record the design process

The data was organised and analysed through qualitative data analysis methods, informed by Miles and Huberman (1994). Each form of data was systematically recorded, archived and assigned an identification code. This aided the relevant grouping of data during analysis, which was organised and reduced into activities. In order to achieve this some conditions were applied to what constituted as a single activity.

It was classed as a single activity if:

- It involved working towards the same outcome, for example the same sketchbook page or digital file.
- It involved the same process without any deviation and if it ran over numerous days then one working day had to lead seamlessly into another without another activity in between.

It was classed as a separate activity if the same process was used on a different day, was not working towards the same outcome and did not lead on seamlessly.

Whilst the activities from the diary log were being identified, they were also annotated and organised. Annotations provided the analyst's insights and because the data described activities carried out by the researcher/practitioner, it was possible to reflect on what the designer was thinking at the time. Perhaps providing an insight into the thought processes and tacit knowledge behind the actions. A map of the design process was created in order to organise the data into a logical format (see Figure 6). Each activity was assigned to a design stage relating to Figure 2, and was represented by a piece of data, which generally consisted of a sentence, or section of a sentence. Descriptive/insightful data was linked to the activities that they were associated with. Links were also made between activities, showing connections relating to what led to or informed another process, for example "Creating yarn wraps" led to/informed "drafting a warp". Colour coding was used within the map to represent whether the activities led to/informed the final designs, whether they did to a limited extent, or did not lead to/inform the final designs at all. Once this had been mapped out, it was possible to begin coding the activities based on what they involved. Some initial categories were identified from the research questions and literature review and they evolved through the coding process. The codes applied are shown in Figure 7 along with their definitions.



Figure 6. An image showing the organisation of data into a design process map

What the process involved - IN		
Efficiency	IN-EF	Where the process was time efficient/cost efficient/labour efficient
Inefficiency	IN-IE	Where the process was inefficient, for example labour intensive/took a long time/cost a lot of money
Exploration/Intuition	IN-EI	Where the process was significantly explorative, relying on tacit knowledge to make decisions
Systematic approaches	IN-SA	Where a systematic approach was utilised as opposed to or as well as making decisions using tacit knowledge, they were pre-planned or adhered to a system
Issues/problems (suitability)	IN-IPS	Where issues/problems of the suitability of the process were involved or highlighted. This includes issues of over complexity
Issues/problems (outcomes)	IN-IPO	Where there were issues/problems with the outcomes or their work in progress
Unexpected results	IN-UR	Where there were unexpected outcomes from the activity or where something was brought to light that hadn't been thought of
Material knowledge generation	IN-MK	Where new knowledge was generated regarding materials
Construction knowledge generation	IN-CK	Where new knowledge was generated regarding construction
Aided decisions	IN-AD	Where the process involved aiding decisions that were made in the design process
Led to a change in direction	IN-CD	Where the activity led to a significant change in direction or re-think
Successful problem solving	IN-SPS	Where the designer dealt with with problems/issues successfully
Unsuccessful problem solving	IN-UPS	Where the designer tried to deal with problems/issues unsuccessfully

Figure 7. Shows the categories that were identified and recorded, with codes and definitions

Findings and discussion

Once the data had been organised and categorised it was possible to search for patterns within it. This section discusses the findings at each stage of the design process.

Concept development

At the concept development stage there was one recorded activity, it was undertaken using a 2D/3D hybrid/non-tangible approach and informed the final designs. Due to the conceptual stage occurring before the project had begun, it was difficult to document it in detail. The activity incorporated theoretical research into hands-on interaction with materials, discussion with colleagues and the evaluation/analysis of a pilot study that was previously undertaken. Therefore demonstrating how a variety of approaches, including previous hands-on interaction with materials can inform design concepts.

Initial research

The most prominent approaches to make up the initial research stage of the design process consisted of 2D non-digital, 2D digital and 3D non-digital.

While 2D non-digital was prominent at this stage, the processes and outcomes did not contribute to the final designs. This points to a lack of suitability for a 2D non-digital approach at this stage. Mainly used to inspire or plan 3D non-digital tasks, when it came to carrying them out, intuition took over and the plan was not used.

2D digital approaches were more suitable, with two out of three activities leading on to inform the final designs. They were used to source materials, which gave the designer access to a wide range of products, however it did not provide a clear understanding of what the material is like. The designer noted, "I will need to wait and see the yarn before making a decision on whether to use it." 2D digital and 2D hybrid approaches were also used to gather and consolidate inspiration in the form of a moodboard. As with sourcing materials, it provided an efficient approach with access to a wide range of information. Digital methods were used as part of the hybrid approach to consolidate information/inspiration from a variety of sources.

3D non-digital approaches also appear to be suitable, with two out of three activities informing the final designs, the other one led to the final designs to a limited extent. The function of them varied from being a planning tool, to providing design inspiration and highlighting areas of concern. However, the knowledge of materials gained was relatively superficial. It became apparent at the in-depth research stage that some of the materials selected using this approach were not suitable.

In-depth research

The in-depth research stage consisted of three approaches, 3D non-digital, 2D digital and 2D non-digital. The majority of the in-depth research was conducted using 3D non-digital/hands-on methods. Forty percent of the 3D non-digital activities informed the final designs and an additional forty percent did to a limited extent. The approach was suitable at this stage but with elements of uncertainty.

Figure 8 shows the comparison between the coding of 3D non-digital approaches, grouping them by whether they informed the final designs, informed them to a limited extent, or did not inform them. The activities that informed the final designs appear to be more efficient and systematic and they aided decisions. In the activities that did not inform the final designs problem solving was unsuccessful and there was a higher degree of inefficiency. While systematic approaches appeared to inform the designs more than explorative/intuitive ones, the material knowledge generation that led to the final designs was gained through unexpected results. This points to the theory that in-depth research of materials has the potential to be valuable within the

design process and can lead to innovation through unexpected results. However, there is no guarantee of useful results and experimentation can lead to dead ends.

The length and uncertainty of the in-depth research of materials in the design process means that it would be problematic to incorporate into a seasonal/commercial design process where designers are subject to time pressures. For this reason it may be that in-depth research of materials would be more suitable as an ongoing and separate activity to the creation of commercial/seasonal products. Additionally, in order for this to justify the time and financial investments necessary there would have to be sufficient potential for innovation.

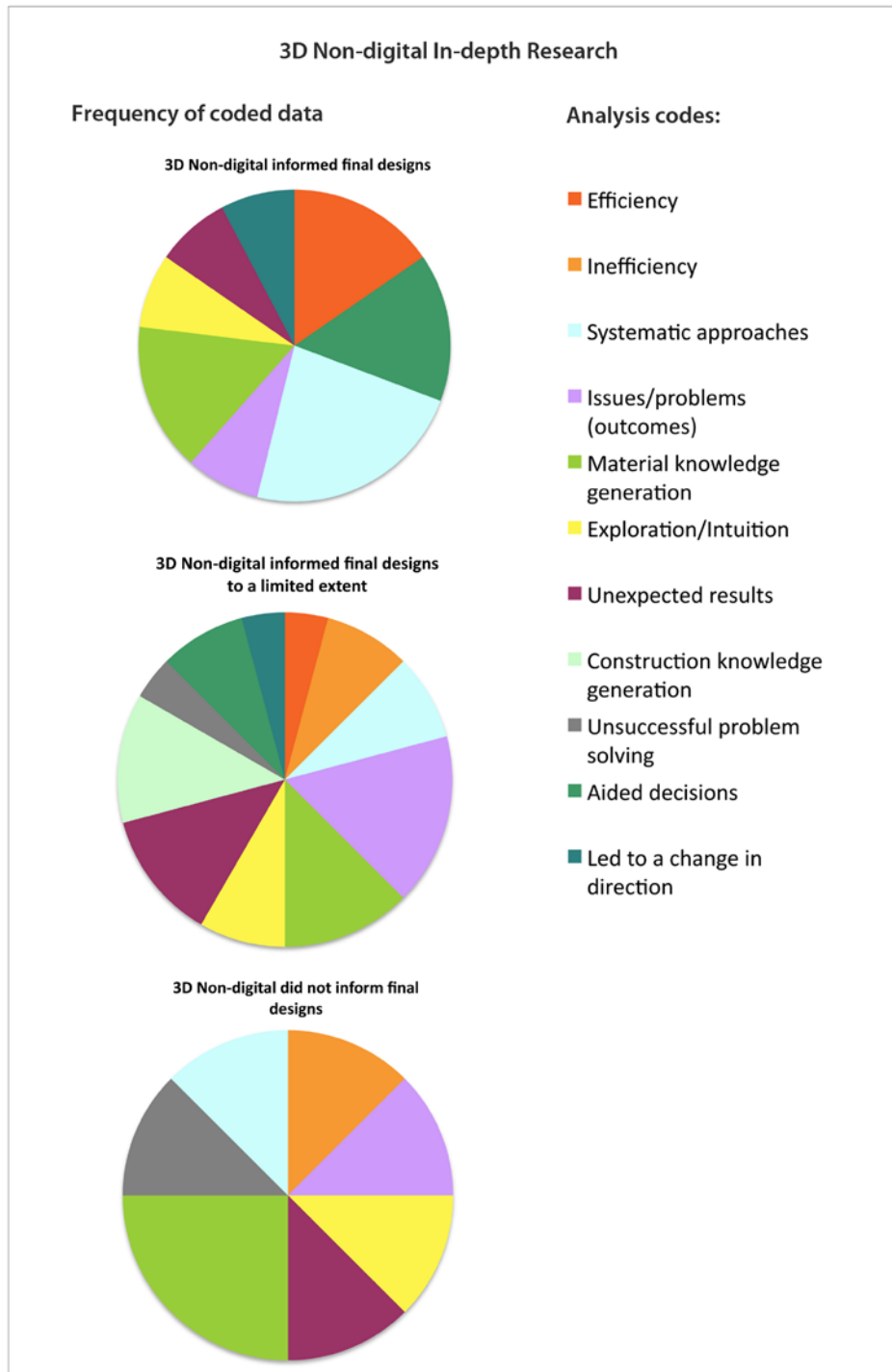


Figure 8. Three pie charts showing the distribution of analysis codes in the 3D non-digital processes used at the in-depth research stage

Idea generation

At the idea generation stage four approaches were used, 2D non-digital, 2D/3D hybrid, 2D/3D non-digital and 2D hybrid. The most prominent was 2D non-digital, which generally consisted of drawing by hand. This appears to reflect to the literature review that points to the suitability of drawing at this stage. It is notable however that the majority of 2D non-digital activities did not inform the final designs and all related to the design of the outsole. A few attempts were made at designing the outsole and it was interspersed between the other activities. The immediacy and efficiency of the approach allowed for this and also meant that a number of attempts could be undertaken. The other 2D method was a hybrid approach and again, this was used with regards to the outsole design. The 2D approaches were generally identified as being intuitive/explorative and involved some elements of efficiency.

2D/3D approaches (non-digital and hybrid) were used for the upper design. They consisted of forming samples around a sandal last in order to generate ideas. These were then developed and recorded in 2D through sketching (see Figure 9). The process used here was much faster than the weaving that was done at both the in-depth research and the design development stages. In each case of this approach being used, form was generated in 3D and then taken into a 2D format. This leads the researcher to question why this was done. It was not described as being purely for the purpose of recording the designs and they were developed on paper. It may be that visualising the design in different formats provided alternative views and aided the development of ideas, or perhaps it was habitual. Drawing can be used to develop the form of an object (Purcell & Gero, 1998, p.392) and it appears that this is how it was used here.



Figure 9. 2D/3D approaches to idea generation

Design development

At this stage 2D digital, 3D non-digital and 2D/3D hybrid approaches were used. The most prominent was 3D non-digital, with the majority of these activities leading to the final designs. The 2D digital approaches all refer to drafting a warp, which is a planning/preparation task, efficiency and systematic approaches were prominent here. This appears to reflect the theory presented in the literature review in which CAD lends itself to practical tasks, leading to benefits in efficiency. The activity itself did not evolve the designs, but allowed for that to happen once the loom was set up. The 2D/3D hybrid approach refers to the evaluation of samples through trying out uppers on the last, photographing them, and making notes/sketching to suggest changes. This is a very similar approach to the one used at the idea generation stage and allows the designer to visualise the design in 2D and 3D.

The 3D non-digital approach mainly consisted of weaving upper designs along with some preparatory tasks, for example yarn wraps and setting up the loom. The charts in Figure 10 illustrate the comparisons of coding distribution between 3D non-digital approaches that informed the final designs and those that did not.

Exploration/intuition was quite prominent in the approach that informed the final designs and did not feature in those that did not. It is possible that this exploration and intuition made the design development successful. Alternatively, it may be that when a design was seen as successful, the designer felt that it was appropriate to evolve it. When an activity led to problems that did not seem solvable or worth solving they were quickly abandoned. For example, alternative structures and materials were tried and dismissed when they did not work as expected. Tacit knowledge was employed to decide if a problem was solvable or worth solving and if there was a need for further exploration. This leads the researcher to believe that the lack of exploration/intuition was a consequence of an unsuccessful design as opposed to a reason. Issues/problems were fairly prominent in both scenarios, however, problem solving only features in the activities that informed the final designs, again, indicating the lack of a perceived need to develop the ideas that in the end did not inform the final designs. Systematic approaches were prominent across both sets of data and so this points to a general systematic process being utilised at this stage.

Presentation

2D hybrid and 2D/3D hybrid approaches were involved at the presentation stage. There were only three activities here so it is difficult to identify patterns. However, it is notable that all of the approaches used are hybrid. This was identified within the data as being “very useful in bringing together the full design as a visualisation.” The outcomes were in both 2D and 3D, and digital processes allowed the designer to consolidate the designs in a 2D format (see Figure 11). Digital methods also have the potential to bring a 2D design to a 3D format through the use of rapid prototyping. This would be more costly and time consuming but it would allow for the designs to be presented as a tangible object. Providing the viewer with more in-depth knowledge of that design.

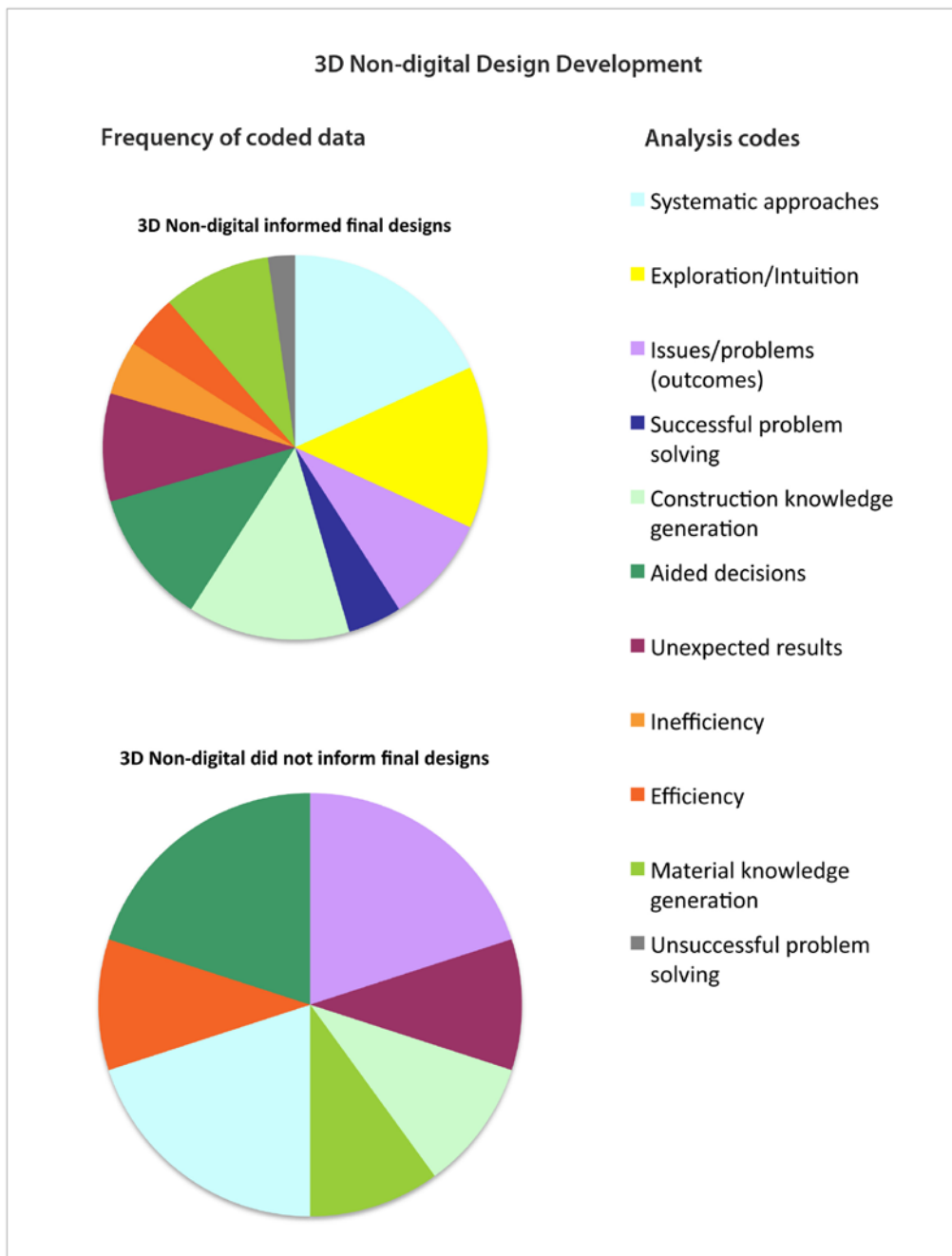


Figure 10. Two pie charts showing the distribution of analysis codes at the design development stage and whether they informed the final designs



Figure 11. Design sheet generated using 2D/3D hybrid approaches

Conclusions

One of the main challenges for a hands-on approach to sandal design lies in issues of cost and time efficiency. The use of weaving to test yarns at the in-depth research stage was time consuming and uncertain in terms of outputs. It was found that innovation may occur through unexpected results and this could be valuable to informing design concepts. This leads to the conclusion that in-depth research through interaction with materials has the potential to be suited to ongoing research that could inform concept development.

Another area of potential for a hands-on woven textile approach was at the design development stage. It required substantial time investment from the designer but the majority of 3D non-digital activities led to the final designs. Where issues and problems were encountered, the designer was able to gain a first hand understanding of the problem and decide whether to solve it or reject the design. The immediacy with which the designer was able to use tacit knowledge in order to do this was a benefit in comparison to more conventional footwear development. Sennett (2009, p.159) reports that through first-hand interaction with materials, flaws can be identified and adjusted by the designer. The findings indicate that hands-on processes have the ability to speed up the decision making process and provide the potential for subjective decisions to be incorporated alongside technical ones.

At the idea generation stage, quick methods of 3D modeling were used in conjunction with sketching. The literature indicates that design ideas can evolve through drawing and that was the case in this project. 3D Hands-on approaches were used to generate ideas and sketching evolved them. The ability to quickly generate new ideas appeared to be key at this stage along with the use of 2D and 3D approaches in conjunction with one another. This points to a need for drawing at this stage, showing that hands-on making could be integrated to inform new ideas, but not replace existing methods.

At the initial research and presentation stages digital approaches were used to consolidate the outputs of a number of different approaches. This was done in a 2D format, however, there is also scope for this to be applied in a 3D format through the use of rapid prototyping.

In summary, there is potential for hands-on interaction with materials to be utilised in the form of a woven textile approach to sandal design. There are key considerations in efficiency within the context of commercial footwear design. The findings indicated that the potential benefits to be gained from hands-on interaction are generation of in-depth knowledge of materials, innovation and control/immediacy in decision-making. Hybrid approaches show potential in incorporating hands-on interaction into a more conventional design process.

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Jenny Gordon

Jenny is a PhD candidate at Loughborough University School of the Arts and a member of the Textile Design Research Group based in this department. She has an educational background in woven textiles and spent a number of years practicing as a footwear designer. She has designed and developed shoes for international markets along with providing colour and trend expertise for the footwear industry. Her background in footwear and textile design informs her research interests, which currently focus on the application of textile design approaches to sandal design. She conducts practice-based research to generate theory through engagement with hands-on design processes. Jenny has presented at international conferences and exhibited selected outcomes of her practice-based research. Recently, she took part in the Textiles Research in Process 2 (TRIP2) exhibition at the Design and Architecture Gallery in Tallinn, Estonia. She is currently working towards the submission of her PhD thesis, expected to complete in 2016.

Faith Kane

Faith Kane is a Lecturer in Textile Innovation and Design and leader of the Textile Design Research Group at the School of the Arts, Loughborough University. Her research interests include sustainable textile and materials design, laser processing for textiles, craft knowledge and interdisciplinary research methods within textile design. She currently supervises five PhD students within these areas. Recent projects include: LEBIOTEX - Laser Enhanced Biotechnology for Textile Design (AHRC); Laser Techniques for Textile Design and Coloration (AHRC); and Textile Thinking for Sustainable Materials (EPSRC). Her research is practice-led and she aims to exhibit the results of her work regularly alongside publishing. Her work was most recently included in 'TRIP 2' (Textiles Research in Process), exhibited at the Design and Architecture Gallery in Tallinn, Estonia. Forthcoming publications include 'Textile Thinking: a flexible connective strategy for concept generation and problem solving within interdisciplinary contexts' (with Rachel Philpott) in *Craftwork as Problem Solving*, edited by Trevor Marchand, published by Ahsgate and 'Crafting Textiles in a Digital Age' edited with Kerry Walton and Nithikul Nimkulrat, published by Bloomsbury. She is also a founder editor of the newly established *Journal of Textile Design Research and Practice* edited by Routledge.

Mark Evans

Mark Evans is a Reader in Industrial Design and leader of Loughborough University's Design Practice Research Group. Prior to joining Loughborough he was a corporate and consultant designer, with clients that include British Airways, Pilkington Optronics and Honda. A PhD supervisor and examiner for 25 candidates with over 100 publications, research activity focuses on supporting creative design practice through the development of tools/resources and understanding the impact of emerging digital technologies. Research has exploited a commitment and passion for professional practice, using insights gained as a practitioner to ensure relevance and maximise impact through a diverse range of media in addition to academic journal publication (i.e. app, web site, video, museum/gallery exhibition, cards, PDF download, product). A significant outcome from this approach has been the iD Cards app-based design tool that was developed/validated/disseminated through

collaboration with the Industrial Designers Society of America (IDSA) and promoted by design associations that include the German Design Council and Design Denmark. Research funding has been received from research councils (EPSRC/AHRC), professional societies (IDSA/Royal Academy of Engineering) and commercial organisations (Hewlett Packard/Unilever) with overseas appointments that include International Scholar at Massachusetts Institute of Technology and visiting professor at Rhode Island School of Design.