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Collaborative user-centred textile design research for healthcare: improving wellbeing and increasing performance

Angharad McLaren[1], Dr Frances Stevenson[2] & Dr Louise Valentine[2]

1. Nottingham Trent University, UK
2. University of Dundee, UK

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Abstract: It has been widely acknowledged that collaboration across disciplines is required in order to develop innovative, sustainable textile solutions that address complex societal problems (Kane & Philpott, 2013; Igoe, 2010). Potential to develop life-changing innovations in the field of advanced textiles for medical and healthcare has been identified as a key growth sector within Scotland, with collaborative cross-disciplinary user-focused design approaches recognised as central to developing new concepts that address human needs (Malins et al. 2012). This paper describes three feasibility studies undertaken by the Textiles programme at the University of Dundee between 2012 – 2014; collaborative design-led research projects that supported local medical and healthcare companies by providing key expertise in textile design, functional clothing design methodologies and user-centred processes for design-led innovation. Analysis and discussion focuses on understanding the challenges and benefits of collaborative research between academia and local enterprise to textile design innovation, local economy, society, and education.

Keywords: innovation, medical, wellbeing, user-centred design, economy.

Introduction

It has been widely acknowledged that collaboration across disciplines is required in order to develop innovative, sustainable textile solutions that address complex societal problems, particularly in the areas of health and wellbeing (see for example Kane & Philpott, 2013; Igoe, 2010; Earley et al, 2010). The Scottish textiles industry is the seventh largest contributor to the national economy with a value of £956 million (Wilson, 2015), and technical textiles (which include textiles for health and wellbeing) is the most rapidly growing sector within this, accounting for 40 percent of turnover despite only 10 percent of the total manufacturing capacity (Malins et al, 2012). Potential to develop life-changing innovations in the field of advanced textiles for medical and healthcare within Scotland has thus been identified as a key growth sector, with collaborative cross-disciplinary user-focused design approaches recognised as central to developing new concepts that address human needs (ibid).

The aim of this paper is to describe and reflect on three Technology Feasibility Studies[i] (2012 – 2014) undertaken at the School of Art and Design, University of Dundee in order to highlight the role of value driven design in cross-disciplinary contexts within the studies. Key objectives are:

1. To understand the challenges and benefits to the stakeholders
2. Gather insights and reflect on the importance of facilitation.
3. To reflect on how these collaborations can influence research and teaching within Academia.
4. Consider how all of the above is influencing the future of textile design.

Textiles at the School of Art and Design, University of Dundee is a value driven programme, with partnership, innovation and craft central to the work and research championed as a key route to its development. Through the Innovation Portal platform, it is cultivating a portfolio of commercially relevant projects specifically within textiles for medical and technical applications, building its wealth of experience in working with small-to-medium sized enterprises (SMEs) in the area of innovative textiles. Its purpose being to identify new design, material and manufacturing opportunities within the Scottish textiles industry, ultimately contributing to knowledge and understanding of design as a means of improving the quality of people's lives.

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Textiles for medical and healthcare

With greater life expectancy and increased health issues in society, advanced technical and smart textiles for medical and healthcare is an area that has been identified as having potential to offer substantial rewards "both in terms of improving existing design solutions and also in developing new technical markets and economic opportunities" (Medical Textiles Report 2012, quoted in Malins et al, 2012).

There are various nuanced definitions of smart textiles, and it is generally agreed that these are materials that will sense, react to and/ or adapt themselves in response to environmental conditions or stimuli, such as biochemical sources or movement (Kettley, 2016; Black, 2007). Technological advances in this area explored within the following case studies include conductive fibres that create biochemical textile sensors (Langenhove et al, 2007), responsive shape memory polymers that change in shape and size (Pause, 2007), and 'wearable technology' which exploit textiles as a soft, flexible surface within which to incorporate electronic systems that can be worn (Kettley, 2016; Braddock, Clarke & O'Mahony, 2005). Benefits of these electronic (e-textiles) in medical and healthcare contexts include the ability to facilitate clinical interaction and monitoring through enhanced comfort, mobility and convenience, potentially with the integration of pervasive, connected systems where integrated electronics can communicate with mobile devices such as smart phones or accessories (Black, 2007). Advanced technology such as this may still be in largely research phases, but it has been recognised that commercial drivers will enable its development towards cost effective solutions appropriate for medical and healthcare applications, often disposable or short-term (Malins et al, 2012; Black, 2007).

Innovation can also lie in the novel application of existing technology in textile products for medical and healthcare (Black, 2007). Scotland is at the forefront of the rapidly developing 'technical textiles' market, offering an unrivalled range of textiles with specific performance or functional qualities (Malins et al, 2012). Moisture absorption and wicking, breathability, anti-bacterial and odour absorption properties embedded within textiles, as well as conceptual ideas leading from the smart textiles developments, have been explored within the case studies in this paper for their potential to bring enhanced comfort and wellbeing to users.

Material choices are also led by consideration of sustainability. As outlined by Kane and Philpott (2013), designers operate within complex problem spaces when developing and/ or selecting materials that have the most positive implications in terms of sustainability and are also commercially and technologically feasible. Knowledge and understanding of the whole lifecycle of materials from both a scientific and design perspective is essential to assess and select the most appropriate choice in relation to the intended product use, to ensure that negative effects are avoided and positive features included (Kane and Philpott, 2013). These considerations are particularly pertinent when aiming for 'positive' features in terms of functionality and must be weighed up in relation to the social implications of the product (ibid). This is particularly relevant in the case studies outlined in this paper, where materials must address extreme functional requirements associated with performance and quality, while also often being disposable or for short-term use and necessarily cheap at the same time (Black, 2007).

It is also important to recognise the tacit qualities that textiles can provide beyond functional performance for their value in health and wellbeing, as elements of these are equally important as functional requirements but are often secondary in this context. O'Connor (2010), for example, discusses how the cultural value of textiles can have their own 'smart' properties without being advanced technologically, due to 'their ability to absorb and convey cultural value and social meaning' through more traditional aspects such as colour, pattern, symbols, and association with the familiar. Different types of materials can embody active and symbolic qualities, Lycra for example giving the wearer enhanced feelings of health, activity, fun, and belonging for its associations with active sports, enhanced performance qualities and innovation, and aerobics / dance movements (O'Connor, 2010). Emotive aspects of aesthetic and tactile

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appeal such as this constitute an important part of a designers' contribution to new product development, ensuring performance in terms of comfort, fit, desirability and social perception. It is in these tacit associations and symbolic qualities that textiles play an important role by adding aesthetic and/or haptic design value to medical and healthcare products in addition to functional properties, helping to ensure user acceptance of products and devices (Black, 2007:12).

Within each case study described in this paper the tacit knowledge of each stakeholder is essential to ensure that the final product is fit for purpose. Clark Moustakas (1990) identifies two types of tacit knowing as 'subsidiary' and 'focal'. Subsidiary is 'visible' or 'describable' and focal relates to the invisible aspects of an experience, which together make a 'whole' experience. In his book, 'Heuristic Research: Design, methodology, and applications', Moustakas cites Michael Polanyi's four types of tacit knowledge which, Moustakas explains, contain subsidiary and focal knowing. The first type is skill, which requires physical or bodily experience, sensory experience, confidence and optimism. Second is 'physiognomy' which he describes through analogy as the ability to read/sense a person's mood through their bodily signals. Third is our capacity to orientate ourselves through 'groping about' to pick up signals that are familiar. Finally, there are speculative skills, which enable people to make a decision about their next move (he uses the chess player as an example). His point is that tacit knowledge is an essential part of research as it allows limitless possibilities for knowing (Stevenson, 2012). These four key types of tacit knowledge are central to designing objects with people, particularly when the stakeholders seek to solve a problem with a material solution.

Design-led approaches

Cross-disciplinary relationships are increasingly forming between textile designers and other diverse fields due to recognition that wider knowledge is required when seeking to address complex societal problems (Igoe, 2010). With reference to the tacit domain, it is clear that the development of smart or technical textile solutions for medical and healthcare requires knowledge spanning various knowledge fields, from scientific knowledge of medical issues, materials science and computing, to commercial and manufacturing expertise from industry, hence the need for collaborative, cross-disciplinary research (Malins et al, 2012).

The value of design is central to this. Key aspects relating to the case studies in this paper include firstly the utilisation of user-centred design methodologies to foster and facilitate deep empathic understanding of users' requirements. Involving users directly in the design process has been recognised as imperative in developing successful design solutions (Malins et al, 2012). Secondly, in design practice making can be seen a form of inquiry, rather than simply realisation of pre-defined ideas, functioning as analysis and synthesis of ideas as part of an iterative design process (Schön, 1983). The ability to explore and develop ideas through prototypes is a valuable process in collaborations in terms of sharing and developing understanding between those involved (Bowen et al, 2016). In each of the case studies presented, prototypes were made as objects to explore ideas, and presented to collaborators - other team members, clients, users or expert consultants - to facilitate feedback, knowledge exchange and improvements and navigate complexities across disciplines.

Design also has the ability to look ahead and visualise future concepts, overcoming the challenges of working with users or collaborators who may be inclined to only base solution ideas on existing tasks, technologies and settings thus inhibiting innovation potential (Talbot, 2000). Creative practice can be described as a "pragmatic inquiry into what might be" (Bowen et al, 2016), which has particular resonance when working with cutting edge 'smart' textile developments outlined previously. In a collaborative context, this also offers opportunity to generate new dialogues and make creative leaps across disciplines to apply design ideas to new or existing industries (Malins et al, 2012).

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Design thinking was adopted in each of the following case studies as it draws upon people's real-world experiences to address modern challenges; it is a human centred design process and in these studies, it was employed to optimise development of the products by bringing the needs of clients, medical professionals, care workers, users, and patients closer together as a way of moving from a concept into a physical working prototype. User-centred design approaches were adopted to explore the feasibility of early stage design ideas through interactive workshops and trials. In each case study, academic project teams worked in collaboration with medical and healthcare focussed SMEs. Insights can be garnered that illustrate the benefits of a design-led approach to collaboration, and in particular the value of sensitivities brought by textile design knowledge and understanding in the development of collaborative solutions for medical and healthcare contexts.

Technology Feasibility Studies (TFS)

TFS 1: Glitter Beach Ostomy Bags

Glitterbeach, an award-winning social enterprise designing, making and supplying swimwear and accessories for stoma patients, proposed a TFS to explore potential textile innovations that could increase the wellbeing of ostomy bag users. Driving this was the Creative Director's first-hand experience as an ileostomy bag user, having encountered problems with their design, materials and usability, and finding these issues widespread among her networks.

A stoma is a surgically created small opening on the surface of the abdomen in order to divert the flow of waste matter from the bladder or bowels, which is collected in an ostomy bag attached to the skin with adhesives and flange systems, changed daily, and may require draining throughout the day and night (McLaren et al, 2012). As a stoma has no nerves and is not sphinctal, it releases output and fills the bag without the patient necessarily being aware, often resulting in leakage and noticeable bulkiness (ibid).

It is estimated that over 13,500 people undergo stoma surgery each year in the UK; the most common underlying conditions resulting in stoma formation are colorectal cancer, bladder cancer, ulcerative colitis and Crohn's disease (Clinimed, 2017). With increased numbers of ostomy bag users worldwide and greater life expectancy, design innovation within this product area offers substantial economic benefits to the Scottish Economy as well as providing enhanced quality, dignity and wellbeing of those living with chronic disease. The study therefore aimed to understand and address ostomy bag issues from the user's perspective in order to develop and prototype design-led solutions. The project team consisted of Dr Frances Stevenson, Academic Head of Design and Craft at University of Dundee; Angharad McLaren, a textile designer, lecturer and researcher with textile industry and enterprise experience; and Patricia Griffin, a textile designer with 30 years' experience as a Registered General Nurse, including care of stoma patients.

Methods

The research used both primary and secondary methods: evaluating potential design interventions, including a review of existing ostomy product innovations, performance materials, and smart textile technologies; interactive design-led workshops with a range of ostomy bag users; semi-structured interviews with clinical professionals; manufacturer research to scope industrial feasibility; followed by iterations of prototyping, testing and evaluation of potential design solutions to reach a resolved outcome for Glitterbeach to take forwards into production stages (Figure 1).

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Findings

Findings confirmed that experience of ostomy bag issues leads to a multitude of psychological and physical problems for users, including decreased fitness levels, low self-esteem, depression, lack of confidence in social and public situations, break down of personal relationships, and lifestyle restrictions. The detrimental effects to both physical and mental health can impact further on the existing medical conditions, causing additional healthcare complications. Key design findings include:

- **Bulk:** needs to be addressed to improve fit for different body shapes;
- **Leakage:** shape and attachments need adjusted particularly neck area;
- **Irritation:** identify quick drying or moisture controlling materials skin to address issues caused by leaks, sweating and moisture under the bag after showering, swimming, or bathing;
- **Discretion:** explore odour absorption and 'quiet' materials to prevent bags rustling conspicuously;
- **Psychological:** 'nude' skin colour bags are negatively associated with 'medical' products.

Figure 1. Left to right: Interactive focus group activities; Prototype development; User feedback workshops.
Source: Angharad McLaren

Outcomes

- Design and production of improved ostomy bag prototypes with improved shape and size to provide enhanced fit, comfort, and usability for a range of body shapes and sizes;
- A professional relationship established with potential local (UK) ostomy product manufacturer to develop ostomy bag designs further through possible licensing routes to manufacture;
- Design and production of ostomy bag accessory prototype to provide increased comfort and wellbeing, using quick drying, wicking-fabric lined spacer fabric for enhanced temperature and moisture regulation.

Future Opportunities

A second strand of enquiry centred on smart sensory textile system concepts with future research and development potential. This explored how to integrate an early warning alert and/ or create barriers when a leak had occurred to allow users extra time to react before experiencing further skin irritation, damage to clothing / bedding, and visible humiliating results. Design concepts include:

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- A subtle, personalised textile sensor system embedded in the ostomy bag or accessory cover, linked to mobile technology.
- Responsive shape memory polymer attachments around the adhesive hydrocolloid attachment to sense leakages and react to prevent it worsening.

TFS 2: MTC Medical Protectors

MTC Medical Protectors is a range of innovative products created by a community care professional who had identified the lack of suitable protection for patients with leg injuries, particularly those with incontinence, to prevent wounds or dressings from contamination when changing soiled clothing. This increases risk of infection to both patients and carers, and in the case of contamination an NHS nurse is required to change them professionally (McLaren et al, 2014). The MTC Medical Protectors were conceived as a result, to provide protection, reduce the pressure on NHS resources, enhance patient and carer wellbeing, and provide a healthier care environment. Four product prototypes (MTC 001 – 004) were presented to the project team with initial design drawings, images and verbal instructions for use.

Those were unavoidably single-use products made from a plastic film, so it was important to the company to source the most environmentally friendly materials. Two of the products in the range needed to be soluble, as the bag and contents would be washed in domestic washing machines. All the other products in the range would be disposed in domestic waste streams, so the client specified that a biodegradable plastic was preferred.

As the products are intended primarily for use in domestic care settings by non-professionals caring for injured or unwell adults, children, or babies, it was also imperative that the product was user-friendly. The company had already selected a manufacturer, established technical and commercial feasibility of the designs, and had a patent application was underway. The TFS therefore aimed to test the products performance and usability from a design perspective, with the objective of improving the prototypes to a near production stage. The project team consisted of Dr Frances Stevenson, Academic Head of Design and Craft at University of Dundee; Angharad McLaren, a textile designer, lecturer and researcher with textile industry and enterprise experience; and Patricia Griffin, a textile designer with 30 years' experience as a Registered General Nurse working in the care sector.

Methods

Firstly, a materials review assessed and sourced appropriate materials from environmental perspective. An ethnographic approach tested product prototypes in workshops that simulated care situations with a range of users – community care workers, nurses, and members of the general public – to gain feedback from a variety of perspectives on: the products design, the materials performance, and instructions for use. Rich experiential data was gathered for analysis from: observation of the trials; reflective questionnaires; interviews; and/ or personal diaries. This aimed to understand the product's usability, specifically: how clear they found the instructions; how safe and secure they felt the product was; how well the product fitted; and how effectively the product performed. Finally, wash trials tested performance of soluble materials in domestic wash cycles. Findings informed prototyping iterations to improve and finalise designs (Figure 2).

Findings

- **Material review:** terminology used to describe 'environmentally friendly' plastics is complex, and can be unclear / misleading. Explored definitions, qualities, environmental credentials and availability of *biodegradable, compostable, oxybiodegradable* and *bioplastics* to assess and identify most suitable for the specific product contexts of use;

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- **Material sourcing:** oxybiodegradable plastic identified as the preferred option, but a commercial source in the required quality (i.e. thin plastic film) was not available at the time; compostable and soluble bioplastic films were sourced due to being most viable and environmentally friendly alternative;
- **Product usability testing**: instructions and position of adhesive tabs confusing;
- **Material testing**: Security of adhesive tabs and strength of material important, especially in the baby product ranges where the patient is often lively and active. Tears occurred when being slid under adult patient's clothing;
- **Instructions**: need to be clearer and include visual prompts in both instructions and on product e.g. arrows. Use wording that encourages a gentler approach, using terms such as 'gently' and 'with care';
- **Overall effectiveness:** participants were reasonably confident in the products effectiveness;
- **Wash trials:** materials dissolved satisfactorily in domestic wash cycles at a range of temperatures leaving no residue on fabrics (e.g. clothing/ bedding), but adhesive strip remained.

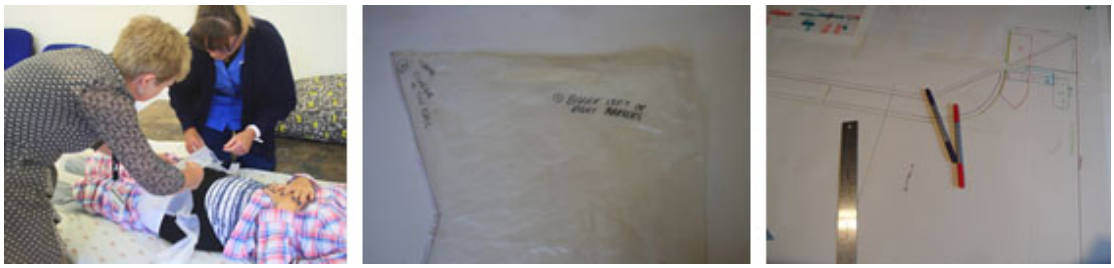

Figure 2. Left to right: User trials; user feedback on prototypes; and prototype design development.
Source: Angharad McLaren

Outcomes

- Testing of four product prototypes to assess product usability, effectiveness and fit and suitability / performance of materials;
- Design and production of improved prototypes and instructions for use for the company's range of four protective medical covers;
- Material performance and wash tests to determine suitability for product applications;
- Recommendations for next steps of product development and testing prior to commercialisation.

TFS 3: Asymmetrical Bra

The Asymmetrical Bra Company (ABC) has developed an innovative medical bra, with patent pending. Dr John Biddlestone designed the concept as a result of his clinical work whilst training in Plastic Surgery at the University of Dundee. John was assisted by the School of Art and Design's Textile Department to develop a working prototype that could lead to commercialisation opportunities. Dr Louise Valentine, Head of Entrepreneurship, Enterprise and Employability at University of Dundee with a background in industrial design, and Claire Adholla, textile designer and lecturer, developed and tested the product concept from a design perspective by creating and testing 3D working prototypes.

The *Asymmetrical Bra* is designed principally for women following breast surgery to improve support, reduce pain and prevent infection and it must not support the deterioration of a woman's health, (i.e. it must not exacerbate the post-operative wound by encouraging MRSA for example, or create a new irritant such as a rash). The context for this new product development is the immediate post-operation phase of a mastectomy i.e. the first two weeks after an operation.

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Methods

Data was gathered via a focus group and cultural probes (Koskinen et al, 2011; Gaver et al, 1999) about 1) how women who are physically affected by breast cancer can, want, or need to use the product, 2) how they perceive the *Asymmetrical Bra* concept and, 3) the design and performance of bespoke prototypes (Figure 3).

Breast Cancer affects all women of all ages and because the largest numbers of women who develop the disease sit in the 50-80 years age bracket, the feasibility study focussed on this demographic. The participants had undergone unilateral mastectomy without reconstruction. There was no restriction of the length of time post-operation. It was essential that their mastectomy wounds were completely healed and they were willing to take part in an initial workshop followed by a weeklong study where they would have a bespoke, asymmetrical garment made for them.

A patient advocacy group was invited for this research study, thereby avoiding theoretical issues of conflict of interest for local patients, the lack of diversity that exists locally while being mindful of the capacity of the temporarily reduced size of the NHS team in Tayside (2014). The patient advocacy group was the St Michael's Breast Cancer Support Group, Cornwall, UK - a well-established and active group.

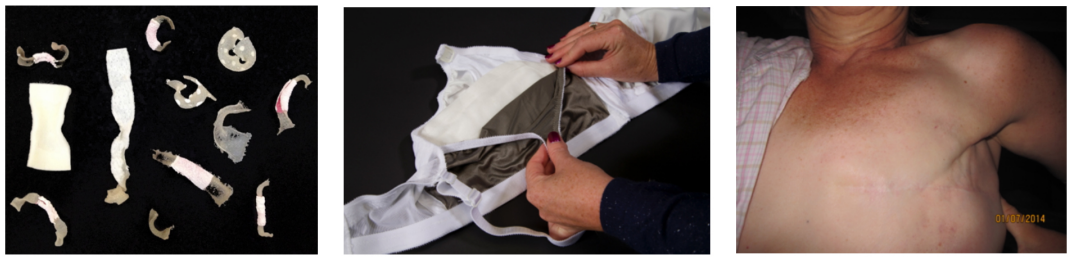

Figure 3. Left to right: Material testing activities; prototype development; cultural probe feedback data.
Source: Louise Valentine

Findings

The type of activity undertaken while testing the five bespoke ABC Prototype 2.0 bras included gardening, shopping, housework and walking. The key design findings include:

- **Bra straps:** good width in the main although one participant would have preferred it to be wider; greater length of straps needed and making an adjustment to the straps needs to be an easy process as women in the 50-80 age bracket may live alone; rubbing and-or irritation was caused and the strapping leaves a distinct red mark on the skin after a couple of hours of wearing;
- **Bra fastenings:** good but the hooks need to be extended, especially the case for the front fastener which 'dug in' because it was not covered; consideration to be given to people who are left-handed as well as right handed;
- **Smart fabric:** X-static Fabric as it is soft and comfortable against the skin.
- **Overall Bra Fabric:** preference for smooth, t-shirt bra material because of the give and flexibility.

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- **Wound Dressing Area:** shape of the wound dressing area is adequate to inadequate. This is an area of the design that is difficult to predict how it will function when needed in specific situations for individual women;
- **Fitting Prosthesis in to the Bra:** does not work;
- **Pocket Position:** requires further consideration as a woman's mastectomy operation scar size impacts on how they responded to this. The most severe was from a woman only one year from her operation with a very large scar;
- **Wash Tests:** held its shape after washing and drying using standard techniques (hand wash and machine wash at 40 degrees); washed well and the inside fabric stayed soft;
- **Overall Fitting:** requires further modifications to enable women not to notice they are wearing a bra and-or be conscious of how their chest area looks to the public when they are wearing close fitting clothes e.g. t-shirt;
- **Overall Look, Feel & Function:** requires improvement in terms of elegance, sophistication and comfort thereby meeting the physical and emotional needs as well as the medical ones

Outcomes

- Testing of six materials to assess which offer the best wound management properties
- Design and production of a working prototype bra
- Testing of five bespoke prototype bras with women who have undergone single breast mastectomies to gain feedback on the look, feel and overall performance
- Insight into the manufacturing requirements
- Next steps for product development and commercialisation

Discussion

The following discussion reflects upon the four key objectives of the paper in relation to the collaborative technology feasibility studies described.

In each case study, the product outcomes of each provide clear benefits to society by providing enhanced comfort, dignity and wellbeing of patients and carers. The collaboration through the Innovation Portal TFS platform allowed companies to explore early stage research and development ideas beyond their own capabilities through funding and specialist academic expertise. This enabled them to develop ideas and take them towards a commercial outcome, offering new design, material and manufacturing opportunities within Scotland.

Development of the Asymmetrical Bra faced difficulties surrounding the high cost of ordering small quantities of high performance smart material for R&D rather than high-level mass production, and the production of bespoke handmade bras. The collaboration allowed access to finance and craft-led design expertise to overcome these and rapidly develop initial ideas to a working prototype stage. All three case studies utilised tacit embodied knowledge of textile design practitioners to make and develop prototypes, and problem-solving skills to overcome challenges of using a wide range of technical materials.

In the Glitterbeach study, a significant challenge was discovered in achieving industrial production of new ostomy products due to extensive clinical trials required for medical product approval. However, establishment of a working relationship with an ostomy bag manufacturer was developed, who agreed to work with the company to develop the product further through industrial prototyping and initial in-house patient trials, with the possibility of full clinical trials and a manufacturing licence agreement if successful. This shows the value of design artefacts – the prototypes – as mediators facilitating

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communication between parties, showing the manufacturer the results of a value driven design-led process with positive improvements for wellbeing and clear commercial potential due to demand for improvements.

Working with a creative design team provided further benefits to Glitterbeach by providing further short-term production (ostomy bag accessory) and long-term research and development (smart textile concepts) options for the company. This led from an understanding developed by working closely with company and gaining insights into their aims and objectives from a commercial and social perspective e.g. to increase their product offerings and therefore potential income for on-going business sustainability, and also satisfy their aim to improve the wellbeing of ostomy bag users.

Complex sustainability decisions were required in the MTC study to select the most appropriate commercially and technologically feasible materials for single-use, disposable and/or soluble products. Understanding the product's lifecycle and specific context of use – domestic care in people's own homes, with products disposed of by either dissolving in high temperature domestic laundry cycles or disposed of in domestic waste streams – as well as the specific definitions, qualities, and impact of so-called 'sustainable' plastics at each stage of the products lifecycle was necessary. The social benefits of the product – improved wellbeing of patients and carers – and the reduced consumption of further materials required for replacement of contaminated dressings were also considered in assessing the feasibility of the product from a sustainability perspective.

Textile design expertise and knowledge of smart textile developments was key to the success of TFS 1 (Glitterbeach) and 3 (Asymmetrical Bra). The ostomy bag accessory was designed using a spacer fabric lined with Coolmax™ lined – a wicking fibre, more commonly used in sportswear, which actively directs perspiration away from the skin to allow evaporation and breathability – for enhanced comfort and wellbeing due to temperature and moisture regulation. These materials were valued by users for both performance and their sporty associations, and were chosen as they were available in a wide range of colour options to disassociate products from the distinctly negative associations of traditional 'nude' coloured medical products. Comfort, functionality, and performance of textiles and product design were also key to the Asymmetrical Bra project, with users reporting the importance of a smooth, flexible fit, and sophistication/ elegance of design as well as the need to offer effective wound management. This combination of haptic, aesthetic and functional qualities was important for desirability, function and consumer acceptance of products that contribute to both physical and psychological health of users.

The Glitterbeach collaboration also introduced advanced smart/ e-textiles ideas to the company, allowing new dialogues around future innovation potential that could support the development of new technologies across disciplines. Design visualisation techniques enabled this to be explored in workshops with users, encouraging them transcend what they perceived to be technologically possible and imagine 'what might be'. The resulting smart, connected e-textile system concepts had the potential to foster future cross-disciplinary textile research, linking market demand with the application of new technologies (Malins et al, 2012).

User-centred design methodologies with an empathic approach were central to each study, allowing the project teams to work closely with users in the design process to understand their perspectives and inform sensitive development of resolved prototype products. Workshops are recognised as an inherent way of working and nurturing creativity in design and design research (Inns 2007, Laurel 2003). They are spaces where practical activities are carried out. Within each case study, collaborative workshops take place in different environments, which are designed to facilitate creative work and understanding of each other's issues, approaches, and priorities. They are places where risk-taking, experimentation, problem solving and aesthetics concerning materials are explored through physical activities. The idea of collaborating through workshop activity seemed the most appropriate way to access and develop ideas

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through connecting, communicating and practicing. Richard Sennett describes the workshop as a centre of co-operative activity (Sennett, 2012) and advocates that at their core workshops are centres of mutuality where social bonds are strengthened through making things, facilitating tacit and explicit knowledge exchange between stakeholders to inform the development of product prototypes sensitive to the specific healthcare context of each study. Each study faced challenges managing the expectations of all stakeholders' due to perceived high need to develop the concept, as well as the highly sensitive nature of the subject, so presenting and testing on-going iterations of prototyping allowed all to understand and contribute to the design development process.

In an educational context, these case studies offer the opportunity to share the experience of new interdisciplinary knowledge and dialogues with students through practical examples of how textile design thinking and practice can be applied in wider societal contexts. They demonstrate the importance of key competencies – cross-disciplinary working and understanding, collaborative decision making, empathy and sensitivity – alongside in depth practical textile design knowledge, skills and understanding required for working in increasingly complex design contexts due to increasing health problems, population size, and life expectancy (Malins et al, 2012), alongside an increasing global sustainability agenda (UN, 2017). They contribute to knowledge and understanding of design as a means of improving the quality of people's lives, encouraging a sustainable future direction for textile design research and practice.

Conclusions

In this paper, empirical accounts of three case studies have been described to demonstrate the value of collaboration between SMEs, academia, industry, users, patients, and medical/ care professionals in the development of textile products for medical and healthcare. Each of the original concepts had potential to provide clear benefits to society by providing enhanced comfort, dignity and wellbeing of patients and carers. The expertise provided by the University research teams was essential to successfully prepare the product prototypes for market, as the companies required expertise in textile design, in the approach and methodology of functional clothing and product design, and user centred design processes to develop prototypes and industrial partnership.

Reflections have revealed the challenges and benefits of cross-disciplinary collaboration, the value of design-led facilitation, particularly in taking a user-centred design thinking approach. Emotional sensitivity, empathy, commercial understanding, and technical integrity were key aspects of the design investigations, facilitated through creative design workshops. As such, these cases can be seen as examples of creative practice that productively created not only artefacts but importantly also a set of relationships between stakeholders to support creative exchange (Bowens et al, 2016). It could also be concluded that the interface between academia, design and health focussed SMEs provided space to develop new interdisciplinary knowledge to generate wider societal benefit and encourage sustainable future textile design directions.

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Note/s

[1] The Innovation Portal, funded by the Scottish Government, aims to promote and foster productive collaboration and knowledge transfer between academia and Scottish industry to support the development of innovative commercial outcomes (Innovation Portal, 2017). Technology Feasibility Studies (TFS) form part of their small grants scheme, allowing Scottish small and medium-sized enterprises (SMEs) to investigate commercial and technical feasibility of an innovation project, research intellectual property position, finance initial testing, and design project frameworks (ibid) within a 12 to 16-week timescale. This platform allows companies to explore early stage research and development ideas beyond their own capabilities through collaboration with specialist academic expertise, helping develop solutions and take them towards a commercial outcome.

Angharad McLaren

Angharad is a Lecturer in Textile Design and Sustainable Clothing Research Coordinator at Nottingham Trent University, and former Lecturer and Associate Researcher at the School of Art and Design, University of Dundee, with prior textile industry and enterprise experience. Research interests include sustainable fashion and textiles, craft theory and practice, textile for performance, health and wellbeing, and relationships between community, place and heritage.

angharad.mclaren@ntu.ac.uk

Dr Frances Stevenson

As a textile practitioner Frances works within the contemporary craft area and strives to create textile products that demonstrate innovation in their design and excellence in their making. As Academic Head of Design and Craft (School of Art and Design, University of Dundee), she believes making processes that combine innovation and excellence are integral to the students learning, both through the challenges encountered within the physical making process and the revelations that manifest themselves through working or reflecting on the process or the finished object. She is particularly interested in the making

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process and the importance of maintaining 'creative buoyancy' as a designer/maker, ultimately raising questions concerning why making and learning through making still matters from a personal, educational, cultural and economic perspective.
f.stevenson@dundee.ac.uk

Dr Louise Valentine
Dr Louise Valentine is Head of Entrepreneurship, Enterprise and Employability for the School of Art and Design, University of Dundee, and Vice President of the European Academy of Design. She was integral to the £8M Digital R&D Fund for the Arts (2011-14), supporting the development of new business models and new ways of effectively engaging with the public. She is a Fellow of the Royal Society of the Arts and Associate Editor of The Design Journal. She studied Industrial Design before gaining her doctoral degree in Design Thinking (2003) and post-doctorates in Craft, Innovation and Partnership Working. Her research focuses on design mindfulness and the value design adds when used as a leadership and performance management tool in business. She is editor of 'Prototype: Design and Craft in the 21st Century' (2013).
L.Valentine@dundee.ac.uk

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